ISSN 0429-9345

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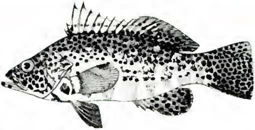
326

Marine fishery resources of the Antilles



Food
and
Agriculture
Organization
of
the
United
Nations

Marine fishery resources of the Antilles

Lesser Antilles
Puerto Rico and Hispaniola
Jamaica
Cuba

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FIAT PANIS

Rome, 1993

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M-43
ISBN 92-5-103183-5

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PREPARATION OF THIS DOCUMENT

This document is a compilation of four papers contributed by scientists from the Greater Antilles region. Although the four papers deal with separate geographical regions: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica and Cuba there is one instance of overlap in coverage. This overlap refers to the US Virgin Islands, that are covered in the chapter of Puerto Rico and Hispaniola, and the chapter on the Lesser Antilles. This is a result of the fact that this archipelago is geographically part of the Lesser Antilles but politically is like Puerto Rico, an US territory. The document was commissioned by FAO to the four authors in light of the need to update the 1981 review of the fishery resources of the Western Central Atlantic Fisheries Commission area (FAO Fish. Tech. Pap. 211), as was recommended by the Sixth Session of the Western Atlantic Fishery Commission's Working Party on Assessment of Marine Fishery Resources. The original manuscripts were subject to substantial technical editing by John Caddy, Jorge Csirke and David Die (FAO-FIRM staff) and any inadvertent alterations in sense or emphasis should be attributed to them rather than to the original authors. All manuscripts were originally written in English except the one for Cuba which was translated from Spanish by FAO. The final version of the document was put together by Erminia Ronchetti (FAO-FIRM staff).

The bibliographic references have been presented as submitted by the authors.

Distribution

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FAO.
Marine fishery resources of the Antilles: Lesser Antilles, Puerto Rico and Hispaniola, Jamaica, Cuba.
FAO Fisheries Technical Paper. No. 326. Rome, FAO 1993
235p.

ABSTRACT

A review of the marine fishery resources of the Greater Antilles archipelago is presented. It includes chapters for the lesser Antilles, Puerto Rico and Hispaniola, Jamaica and Cuba. In each chapter a description of the oceanography and physical characteristics of the islands, their coastline and surrounding seas is included. Detailed summaries of the biology and status of stocks of the most important resources, including reef fish, large pelagics, flyingfish, coastal pelagics, queen conch, shrimp and spiny lobster. Special references are made to resource management and ciguatera.

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PART 1

LESSER ANTILLES

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ABSTRACT

A review of the marine fishery resources of the Lesser Antilles archipelago is presented. It includes a description of the oceanography and physical characteristics of the islands, their coastline and surrounding seas. Detailed summaries of the biology and status of stocks of the most important resources, including demersal fish, large pelagics, flyingfish, coastal pelagics, queen conch, sea urchins and spiny lobster.

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1. INTRODUCTION

Fishing is of considerable importance to the islands of the Lesser Antilles in the West Central Atlantic Fishery Commission (WECAFC) region. While the available statistics indicate that in most islands the fishery sector accounts for 4-10% of the GDP, the true value of fishing has not been accurately estimated. To begin with, total landings are poorly estimated in many islands particularly for the most dispersed artisanal fisheries in which much of the catch is consumed locally. The value added component of fishery products, particularly those consumed in the tourist industry, is seldom taken into account. Finally, the value of recreational fishing and associated expenditures by tourists is seldom considered.

Most of the fishery resources of the island shelves -- reef fish, lobster, conch -- are considered to be overexploited, and in need of rehabilitation. The deeper demersal resources -- snappers and groupers -- have been overexploited in several islands, and are coming under increasing fishing pressure throughout the subregion. Extended jurisdiction has brought promise of increased yield of offshore pelagic resources, and the associated responsibility for assessing and managing stocks which are shared or migratory (Mahon, 1987).

The information base for resource assessment and management of the major fisheries in the sub-region is patchy and scant. Likewise, the institutional capability for assessment and management is variable, and with the exception of the French islands and the U.S. Virgin Islands, expertise and funds for these activities are severely limited (Freon et al., 1991).

This review will attempt to summarise the current state of knowledge about, and the status of, the fishery resources of the Lesser Antilles subregion. The focus will be primarily on research and assessment activities carried out in the subregion. Much of what is known about the resources in this area is extrapolated from studies on the same species and types of fisheries elsewhere in the wider Caribbean. There will be no attempt at a review of the wider information base. However, for the sake of continuity, and in order to make the review self contained, brief synopses of available information from other areas have been included in several places.

2. PHYSICAL DESCRIPTION OF THE LESSER ANTILLES

2.1 Characteristics of the Islands, Their Shelves and EEZs

The Lesser Antilles subregion, which extends from the U.S. Virgin Islands south to Grenada, comprises one of the most compact aggregations of nations in the world (Figure 1). In addition to seven independent island nations (St. Kitts and Nevis, Antigua and Barbuda, Dominica, St. Lucia, Barbados, St.Vincent and the Grenadines, and Grenada), there are dependencies of the United

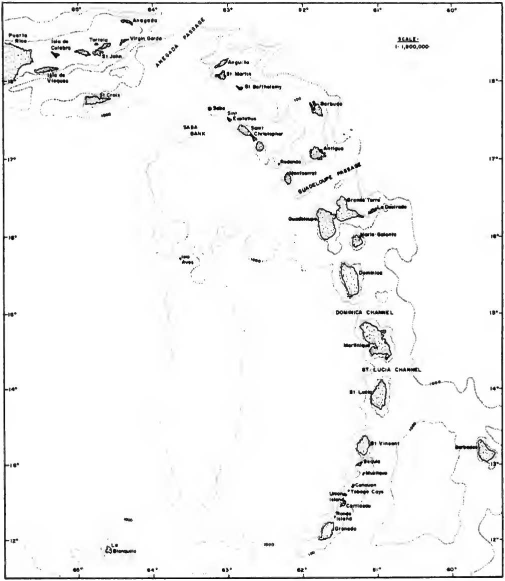

Fig. 1. The Lesser Antilles subregion with island shelves and banks

Kingdom, (British Virgin Islands, Anguilla, Montserrat), and of The Netherlands (St. Maarten, Saba and St. Eustatius), Departments of France (Guadeloupe, St. Martin, St. Barthelemy, and Martinique) and territories of the United States of America (US Virgin Islands).

The islands of volcanic origin are characteristically mountainous and forested. These are (from south to north): Grenada, St. Vincent, St. Lucia, Martinique, Dominica, the Grande Terre of Guadeloupe, Montserrat, Nevis, St. Kitts, St. Eustatius, and Saba. In these islands, the shelf is usually narrow, sometimes less than 100 m (Figure 2). Owing to their elevation, they usually have considerably more rainfall than the coralline islands. Consequently, numerous permanent rivers occur, the majority of which discharge on the west coasts.

The limestone islands, e.g., Anegada, Anguilla, Barbados, St. Maarten/St. Martin, Antigua and Barbuda, are typically flatter and experience less rainfall than the volcanic islands; thus permanent rivers are few. The submarine platforms of these islands are generally extensive. Barbados is an exception to this pattern with a relatively narrow island shelf.

Most of the countries of the Lesser Antilles have declared 200 mile Exclusive Economic Zones (Figure 2). Therefore, many of them have jurisdiction over extensive areas of ocean to the east of the island arc. In a few cases, the equidistant lines between countries cut across banks and island platforms (Figure 2, Tables 1 and 2) creating several situations in which cooperative management of demersal resources will be required (Mahon, 1987).

2.2 Marine Habitats

The Lesser Antilles subregion includes the full range of tropical marine and coastal habitats: estuaries, mangrove lagoons, seagrass beds, fringing reefs, patch reefs and barrier reefs, the slopes of the island platforms, deep bank reefs, and open ocean. The extent to which these habitats can be found in association with the various islands depends to a large extent on whether the island is volcanic or limestone. Due to the freshwater and sediment inputs of the rivers which occur on the volcanic islands, nearshore coral reef development is usually minimal, particularly on the western shelves. In the limestone islands, coral reefs tend to be well developed.

Submerged early Holocene or late Pleistocene reefs up to 90 km long and with bottom relief about 20 m are a common sublittoral feature of the eastern Caribbean area (MacIntyre, 1972). They occur on the outer edges of island shelves at depths of 30-80 m. They are generally dead and covered by only a few scattered living corals, as observed by echo-sounder profiles, rock dredging, bottom photographs and in situ observations off the Virgin Islands, St. Martin, St. Barthelemy, Montserrat, Guadeloupe, Martinique, St. Lucia and the Grenadine Islands.

Table 1. Area and length of slope (100 fathom or 200 m contour) for island shelves, banks and parts thereof occurring within EEZs as defined by the equidistance principle (Figure 2).

	Shelf (km^2)		Slope (km)	
Shelf or Bank	Parts	Total	Parts	Total
USVI total		1,972		
St. Croix shelf	343			
St. Thomas/St. John shelf	1,629			
BVI shelf		3,133		176
Anguilla total		2,391		170
Anguilla shelf	2,208		124	
Bank E	20		16	
Sombrero Bank	41		30	
2 Banks N and NE	82		40	
Bank SE	41		20	
Saba total			1,713	237
Saba shelf	20		24	
Saba Bank	1,667		173	
Bank N of Saba	26		40	
St. Eustatius		113		46
St. Maarten		50		10
St. Martin and Barthelemy		1,660		152
St. Kitts and Nevis total		845		178
St. Kitts and Nevis shelf		595		156
Anguilla shelf (piece)	250		22	
Antigua and Barbuda total		3,568		393
Antigua and Barbuda shelf	3,400		264	
Bank S.	40		20	
Anguilla shelf (piece)	7		23	
Redondo shelf	98		62	
Havers Shoal	5		8	
St. Kitts/Nevis shelf (piece)	18		16	
Montserrat total		146		123
Montserrat shelf	106		53	
Bank SW	40		20	
Long bank SE	80		50	

	Shelf (km^2)		Slope (km)	
Shelf or Bank	Parts	Total	Parts	Total
Guadeloupe total	1,649		511	
Guadeloupe shelf	1,323		300	
Marie Gallante shelf	101		58	
Bank E	40		20	
3 Banks N	117		90	
Bank W	40		20	
Bank between Guad. & MG	28		23	
Dominica total		303		146
Dominica shelf	251		126	
Bank SE (part)	52		20	
Martinique total		1,013		219
Martinique shelf	914		171	
Bank NE	47		28	
Bank NE (part)	52		20	
St. Lucia total		522		144
St. Lucia shelf	407		136	
Bank NE	7			
Bank S	6			
Barbados total		277		127
Barbados shelf	230		98	
Bank SE	47		29	
St. Vincent/Grenadines total		1,800		228
St. Vincent shelf	111		80	
Grenadine Bank	1,689		148	
Grenada total		1,595		231
Total		22,751		3,091

Table 2. Areas for EEZs, shelves and banks, and lengths of slopes around shelves and banks (100 fathom or 200 m contour) for Lesser Antilles countries. Approximate estimates of potential yield for various resources, are presented here together with available estimates of landings. These are discussed in the sections dealing with the specific resources (-- = no information found).

		Shelf				Slope				Lobster		Conch		
Island/Country	EEZ[1] (km^2)	Area[2] (km^2)	Yield[3] (mt/y) Min.	Yield[3] (mt/y) Max.	Land. (mt/y)	Length[4] (km)	Yield[5] (mt/y) Min.	Yield[5] (mt/y) Max.	Land. (mt/y)	Yield[6] (mt/y)	Land. (mt/y)	Yield[7] (mt/y)	Land. (mt/y)	Total[8] landings (mt/y)
USVI		1,972	986	7,888	--	--	--	--	--	99	50	118	32	--
BVI	84,050	3,133	1,567	15,665	397	176	25	111	--	157	36	188	--	690
Anguilla		2,392	1,196	11,960	--	170	24	107	--	120	128	144	24	485
Saba		1,713	857	8,565	--	237	33	149	--	86	5	103	--	--
St. Eustatius		113	57	565	--	46	6	29	--	6	--	7	--	--
St. Maarten		50	25	250	--	10	1	6	--	3	--	3	--	--
St. Martin/Barthelemy		1,660	830	8,300	--	152	21	96	--	83	--	100	--	--
St. Kitts/Nevis	20,400	845	423	4,225	722	178	25	112	--	42	30	51	82	1,500
Antigua/Barbuda		3,568	1,784	17,840	800	393	55	248	--	178	113	214	--	2,400
Montserrat	21,100	146	73	730	--	123	17	77	--	7	0	9	10	111
Guadeloupe	26,200	1,649	825	8,245	--	511	72	322	--	82	100	99	300	8,233
Dominica	10,200	303	152	1,515	46	146	20	92	32	15	2	18	--	650
Martinique	13,000	1,013	507	5,065	--	219	31	138	--	51	100	61	50	3,060
St. Lucia	4,700	522	261	2,610	--	144	20	91	--	26	9	31	--	945
Barbados	48,800	277	139	1,385	--	127	18	80	45	14	1	17	--	9,097
St. Vincent	9,500	1,800	900	9,000	--	228	32	144	--	90	14	108	5	712
Grenada	7,700	1,595	798	7,975	130	231	32	146	--	80	15	96	30	2,001
Total		22,751	11,376	111,783		3,091	431	1,947		1,138		1,365		

[1] EEZs (Shepard, 1989) are for illustration only, and do not reflect an opinion concerning the delimitation of boudaries or frontiers of any country.

[2] Shelf areas, compiled from various sources, include banks and parts of other island shelves bisected by boundaries as per Table 1, and Figure 2

[3] Shelf yield based on a range of 0.5-4.0 mt/km^2/yr, from sources described in Section 3.3

[4] Slope lengths, compiled from various sources, or estimated by the author, include areas of banks and parts of other island shelves as for 2 above.

[5] Minimum slope yield 222 kg/nautical mile/yr (Polovina and Ralston, 1986), maximum slope yield based on Olsen's (1984) estimate of 1255 kg/km^2/yr

[6] Lobster yield based on estimate of 0.05 mt/km^2/yr, as described in section 3.3 (CFMC, 1984; Olsen, 1984)

[7] Conch yield based on estimate of about 0.06 mt/sq. km/yr (Appeldoorn in press b; Olsen, 1984)

[8] Total landings taken from FAO Fisheries Yearbook Vol. 66, 1988, unless otherwise indicated.
USVI: Lobster (CFMC, 1990), conch (Mahon, 1987)
BVI: Landings, average. 1975, 1978, 1982 (Klausing, 1979)
Anguilla: Landings (Jones, 1985)
St. Martin/Barthelemy:
St. Kitts/Nevis: Fishery specific landings (Olsen, 1984)
Antigua/Barbuda: Fishery specific landings are for 1981 (Anderson and Matthes, 1985a)
Dominica: fishery specific landings are for 1985 (Anon., 1986)
Martinique: Landings are for 1987 (Gobert, 1990)
Barbados: deep slope landings (Prescod, 1991)
Grenada: Fishery specific landings are average for 1979-1981 (Finlay, 1983)

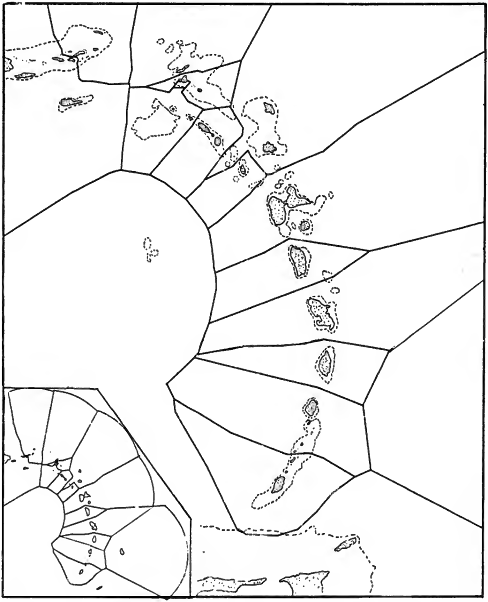

Fig. 2. EEZs of the Lesser Antilles subregion, based on the equidistance principle, taken from a map prepared by the Dalhousie Ocean Studies Program, Dalhousie University, Halifax

The most complete maps of coastal marine habitats for the islands of the Lesser Antilles are in the series of Preliminary Data Atlases, prepared by the Eastern Caribbean Natural Area Management Program, and distributed by the Caribbean Conservation Association. There is also a variety of studies which include descriptions of the coastal habitats in the islands of the Lesser Antilles. These are briefly reviewed for each island in alphabetic order below.

Marine habitats were mapped for eight sites around Anguilla, and their fauna and flora surveyed (Oxenford and Hunte, 1990).

In Antigua, Price and John (1977) describe the marine habitats. Subsequently, John and Price (1979) examined the distribution and zonation of organisms at nine localities and described four basic habitats: (1) Rocky inshore, primarily intertidal; (2) Bays and fringing reef lagoons (these were sheltered with sand/silt substrates commonly covered by dense beds of Halodule and Thalassia); (3) Coral reef areas with typical zonation across the reef crest; and (4) Mangrove areas (shallow bays and inlets fringed by red mangrove). A recent study has mapped the substrates of the entire Antigua/Barbuda shelf.

In Barbados most of the studies of coastal marine habitats have been carried out on the south and west coasts. Lewis (1960) described the zonation of fringing reefs and associated fauna. James et al. (1977) provided a detailed description of a section of the shelf off the west coast of Barbados, including fringing reef, a rubble area, a bank reef, and sand flat. MacIntyre (1967) described two submerged barrier reefs parallel to the west coast of Barbados, and used a sea sled and aerial photographs to map the west coast of Barbados (MacIntyre, 1968). In 1984 the south and west coasts were mapped using aerial photographs, echo sounder, and ground truthing surveys (Mahon and Hunte, 1985). The deeper relict west coast reefs have been examined using a submersible, and found to be sponge dominated (MacIntyre et al., 1991).

In the British Virgin islands Dunne and Brown (1979) described the barren, fringing and patch reefs in 22 localities around Anegada and produced maps of corals and algae distribution and of relative abundance of fish in various habitats. In a further study of patch reefs in the lee of Anegada they examined the effects of currents on the zonation and orientation of patch reefs (Brown and Dunne, 1980).

Marine habitats have been mapped in Grenada in the vicinity of Grande Anse Bay and Point Salines (Hunte, 1987a). This includes several depth profiles, and habitat distribution along several transects.

The reefs of Guadeloupe, Marie Galante and Desirade have been inventoried by Battistini and Petit (1979). The reefs have several distinguishing features, their morphology resulting from three different types of formations: corals, algal constructions, and arrecifes.

Battistini (1978) describes the coral reefs of Martinique, which are restricted to the east and south coasts. On the windward, east coast, a barrier reef, largely drowned at 5-10 m depth, except for the cays (Pariadis, Pinsonnelle, and Loup Garou), stretches for 25 km. It is cut by passages and isolated from the coastline by a lagoon and includes many micro-lagoons in their flats. On the reefs facing the oceanic surf, algal ridges grow built by calcareous encrusting algae which are only exposed at low tide. There are also extensive areas of brown soft algae (mostly *Sargassum*). Adey *et al.* (1978) described the Holocene reef systems of eastern Martinique. The applicability of using LANDSAT for mapping of coastal habitats was examined in Martinique (West and Richardson, 1987).

Saba Bank, a large submerged island in the northeastern Caribbean is flat-topped with depths of about 20 to 40 m (Van der Land, 1977). There are several reefs around the periphery of the bank and shallow water stony corals in the area. As an atoll, the Saba Bank is remarkable for its large surface area, the height of most of its Holocene reefs and the width of its windward reef flats.

Roberts (1972) provides a general description of coral reefs growing in the coastal waters of St. Lucia. They consist of two general types: (1) patch and platform reefs, and (2) incipient fringing reefs. Both reef types were studied along the southeastern coast, where reef growth is most prolific. Five distinct biological zones were recognized. Reef development on the St. Lucia shelf is not extensive. Detailed surveys have been carried out on the flora and fauna of six reefs on the west coast of St. Lucia (CEHI, 1990).

The distribution, species composition, and zonation of reefs on the island of St. Vincent are described by Adams (1968). In the Grenadines, Lewis (1975) has mapped the Tobago Cays and the Horseshoe Reef and shown zonation of the reef. Habitat maps showing *Thalassia* beds, corals, rubble, alcyonarians, and sand are presented for Petit Rameau, Petit Bateau, Baradal, and Jamesby.

Marine habitats have received the most study in the US Virgin Islands. Kumpf and Randall (1961) mapped the major marine habitats of St. John, Virgin Islands down to the 10-fathom contour using aerial photography and a diving sled for ground-truthing. The shallow coral reef and algal ridge systems on the eastern shelf of St. Croix are described and mapped (Adey, 1975), as is the Buck Island off the north coast (MacIntyre and Adey, 1990). The bank barrier reefs of St. Croix are of the 'fleshy algal pavement' type (with *Sargassum* spp. especially common). This reef type is characteristic in areas of high turbidity. Gerhard (1981) provides habitat maps of the Candlelight reef, Coakley Bay system (St. Croix). LANDSAT imagery was used for habitat mapping and inventory

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by Armstrong (1983) and navigation charts were used to quantify the proportions of various substrate types on the shelf around the US Virgin Islands (CFMC, 1984).

2.3 Climate and Oceanography

Knowledge of the seasonal patterns of variability in the ocean/atmosphere systems of the tropical Atlantic has recently increased significantly due to several key projects. However, much of this work has been in the eastern and central Atlantic, and although relevant to the western Atlantic, does not provide specific details for the eastern Caribbean area. In spite of these limitations, it is possible to develop a general picture for the seasonal patterns in the ocean climate in the western tropical Atlantic.

The seasonal cycle is dominated by the annual displacement of the Intertropical Convergence Zone (ITCZ) northward, beginning in April-May, to its northernmost location at about 10°N in August-September, and its return to its southernmost location just south of the equator in January-March. The seasonal cycle associated with the displacement of the ITCZ can be summarised as follows:

ITCZ North (June-November)	ITCZ South (December-April)
High rainfall	Low rainfall
Increased cloud cover	Clear sky
Low wind speed	Strong NE trade winds
Low current speed	Strong surface currents
Warmest temperatures	Coolest temperatures
Low atmospheric pressure	High pressure

This seasonality affects the physical oceanography in the region in the following way. When the ITCZ is at its northernmost location (October-November), and easterly wind stress is minimal, a North Equatorial Counter-Current develops (Garzoli and Katz, 1983). This takes off a large proportion of the Guiana Current, and appears to entrain much of the nutrient-rich outflow of the Amazon River. At this time, easterly surface currents flowing towards the Caribbean consist mainly of nutrient-poor water from the North Equatorial Current, and the influence of the Amazon outflow on the waters of the eastern Caribbean is minimal (Muller-Karger et al., 1989; Richardson and Walsh, 1986).

During the above period of the year, the nutrient-rich plume of the Orinoco River appears to disperse to the northwest, through the eastern Caribbean towards Puerto Rico. Mesoscale eddies to the east of the island arc, or occasional westerly winds created by low pressure systems to the east of the island arc, may also disperse

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this water to the northeast, occasionally as far as Barbados (Muller-Karger et al., 1989; Muller-Karger, 1990).

During the opposite period of the year (December-April), when the ITCZ is at its southernmost location, there are strong Trade Winds across the north Equatorial Atlantic, the North Equatorial Counter-Current breaks down, and the rates of flow of the North Equatorial Current and the Guiana Current are greatest.

During this period, the outflow of the Amazon River is entrained to the north and west by the North Equatorial Current and Guiana Current, and has its greatest influence on the eastern Caribbean subregion (Muller-Karger et al., 1989; Muller-Karger, 1990; Richardson and Walsh, 1986). At this time of year, the outflow of the Orinoco River is also entrained by the westward flowing currents and is carried west along the north coast of South America (Gade, 1961; Muller-Karger, 1990).

The Amazon waters moving towards the eastern Caribbean are dispersed in large patches, which contrast in physical and biological characteristics with the waters of the North Equatorial Current (Ryther et al., 1967; Calef and Grice, 1967). The effects of the Amazon water, and of the Guiana Current, on the physical and biological oceanography in the vicinity of Barbados, are such that there is a seasonal signal in salinity due to the Amazon water, and a shorter term variability due to the meanders in the Guiana Current (Borstad, 1982a; 1982b; Kidd and Sander, 1979).

Although the mean monthly circulation patterns suggest smooth current flows in the Lesser Antilles subregion, recent research shows that there are complex systems of gyres and eddies both east and west of the Lesser Antilles. Ingham and Mahnken (1966) noted that flocks of seabirds and schools of fish are frequently associated with the latter. East of the island chain, some eddies form in the wake of Barbados, others are caused by the piling up of water against the island arc (Mazieka et al., 1980).

Little is known about the inter-annual variability in climate and oceanography in this area. According to Hastenrath (1988) climatic variability is primarily due to enhancement or reduction of the normal seasonal cycle. Most studies have been too short to reveal the seasonal and interannual variability of the current features described above. A survey by Mazieka et al. (1980a, 1980b) shows similar eddy patterns between Tobago and Grenada in two winter periods, 1977 and 1979. Febres-Ortega and Herrera (1976) found a cyclonic gyre east of Tobago in August 1972, and Johanesson (1971) found an area of current moving southeastward in an hydrographic section from Barbados to Tobago in August. Brucks (1971) shows an eddy just north west of Barbados. There are also systems of eddies west of the island arc (Leming, 1971; Molinari, et al., 1981; Heburn et al., 1982). These are characteristically found in the wakes of islands and their variability will depend on the variability of flow through the island passages (Stalcup and Metcalf, 1972; Mazieka et al., 1980).

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2.4 The Fisheries

The fisheries of the islands of the Lesser Antilles have been described in numerous publications which cannot be fully reviewed here. Abstracts of most of the earliest references can be found in Mahon, et al. (1984). Some which are not cited in that review, and other more recent ones are listed below by island/country. These indicate the types of fishing vessels, gear, landing sites and distribution patterns.

Anguilla: Jones (1985); Stephenson et al. (1988).

Antigua/Barbuda: Mahon et al. (1982); Chakallal (1982); Ben-Yami (1983); Berleant-Schiller (1983); Joseph (1984); Goodwin et al. (1985); Anderson and Matthes (1985a); Martin et al. (1988).

Barbados: Ben-Yami (1983); Bell et al. (1988).

British Virgin Islands: Klausing (1979); Dibbs (1981); DOSP (1985); Blok et al. (1988).

Dominica: Holness (1981); Ben-Yami (1983); Philbert (1984); Mounsey (1984); Goodwin et al., 1985); Anderson and Matthes (1985b); Mitchell and Gold (1986); Lawrence et al. (1988).

Grenada: Goodwin et al. (1985); Finlay and Rennie (1985b); Kawaguchi and Cortez (1985); Finlay et al. (1988).

Guadeloupe: Ben-Yami (1983).

Martinique: Ben-Yami (1983); Abbes (1984); Gobert (1988, 1989).

Montserrat: Ben-Yami (1983); Jeffers (1984); Goodwin et al. (1985); Jeffers et al. (1988).

Saba: Zaneveld (1962); Guidicelli and Villegas (1981).

St. Barthelemy: ECNAMP (1983); Lorance (1989).

St. Eustatius: Zaneveld (1962); Guidicelli and Villegas (1981).

St. Kitts/Nevis: UNDP/FAO (1984); Olsen (1984); Goodwin et al. (1985); Barrett et al. (1988).

St. Lucia: Ben-Yami (1983); Murray (1984); North-South Intermedium (1984); Goodwin et al. (1985); Murray et al. (1988).

St. Maarten/St. Martin: Zaneveld (1962); ECNAMP (1983); Lorance (1989).

St. Vincent and the Grenadines: Anderson et al. (1982); Ben-Yami (1983); Matthes (1984); Morris (1984); Chakalall (1985); Goodwin et al. (1985); Morris et al. (1988).

U.S. Virgin Islands: Olsen (1983); de Graaf and Moore (1987).

In general, fishing takes place from small boats, 4-12 m in length, from small landing sites, using traps, handlines, beach seines, and more recently, short surface and bottom set longlines. During the past 10 years, several "fishery complexes" have been built, to provide better facilities for fishermen, and to facilitate handling and marketing their landings. There has also been a trend towards larger boats, particularly in Barbados (Mahon, 1990a). A full review of fishery development activities in the subregion is outside the scope of this report.

3. FISHERY RESOURCES

Fisheries in the Lesser Antilles subregion are based on a few major resource types and some minor ones. The major resource types are: lobster, conch, shelf and slope demersals, large pelagics, coastal pelagics, and flyingfish. Each of these will be reviewed in a separate section below. The minor resources are reviewed together. Landings of the various fishery types by the countries are summarised in Table 2.

3.1 Spiny Lobster

3.1.1 Overview of the fishery

Spiny lobsters are fished on the island shelves primarily by traps and divers using snares (loops), although trammel nets are common in Martinique. *Panulirus argus* is the most abundant and commercially important of the three Caribbean species of this genus. The others are *P. guttatus* and *P. laevicauda*. They have a high market value and most of the catch is exported or sold to hotels and restaurants (Goodwin *et al.*, 1986; Appeldoorn *et al.*, 1987; Mahon and Rosenberg, 1988). Owing to the value of the resource, lobster fishermen are well off relative to fishermen who target shelf fishes, or pelagics from small craft. Tourism development in most islands has increased, such that in many cases islands have gone from exporters, to importers of spiny lobsters. U.S. imports from the Leeward Islands increased from 40 mt (live weight) in 1960 to 548 t in 1978 then dropped to 27 mt in 1980 (DuBois, 1985; Appeldoorn *et al.*, 1987).

Lobster remains the single most valuable fishery resource in the Lesser Antilles. Catch estimates from Lesser Antillean islands are poor or lacking. Therefore, it is not possible to properly estimate the current value of the fishery. However, rough estimates of potential yield suggest that the annual yield from the island shelves and banks of the Lesser Antilles (except US Virgin Islands) should be about 1,000 mt. At an average price of US$2.50/lb., the total wholesale value of this yield would be about US$ 5.5 million. The retail value of this yield in restaurants at about US$ 10.00 per 500 g plate would be about US$40 million, most of which would be foreign exchange.

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High demand for the Caribbean spiny lobster has resulted in overexploitation in most islands, especially those with small shelf areas, and depletion is inevitably most severe in easily accessible areas and depths (Mahon, 1987; Appeldoorn et al., 1987).

In Antigua and Barbuda lobster are fished with fish traps and by divers with wire loops (Peacock, 1974). Most of the catch is Panulirus argus, with P. guttatus and P. laevicauda being occasionally caught. In Barbuda, diving is more important than traps and occurs in inshore lagoonal areas and nearshore reefs. In Antigua, the trap fishery is most important. The landings of lobsters declined between 1968 and 1972 at a rate of about 15% per annum. A detailed description of fishing technology and practices in Barbuda contrasts the lucrative lobster fishery and subsistence reef-fish fishery (Berleant-Schiller, 1983).

On the Grenada Bank lobster stocks appeared to have been depleted by 1964 and could no longer support the scale of fishery which had developed (Adams, 1972). However, in the Grenadine Islands, Chislett and Yesaki (1974) report viable commercial fishing by an 80' converted shrimp trawler which, with another smaller boat, raised 250 traps twice a week to catch 90-140 kg of whole lobster. The average weight was reported at 1.6 kg and median weight at 0.7 kg. Fishing was in the area between Union, Mayreau and Petit Martinique Islands and the edge of the shelf.

In Martinique, an assessment of lobster stocks indicated that P. argus is overexploited, mainly by traps, while P. guttatus, which is fished primarily by trammel nets, is underexploited, probably due to its small size and use of different habitat than P. argus (Gobert, in press c)

Lobster landings in St. Thomas and St. Croix, US Virgin Islands, show no significant trends between 1980-81 and 1987-88, and CFMC (1990) concluded that the US Virgin Islands lobster fishery was healthy.

Until recently, lobster management in the Lesser Antilles consisted of a variety of size limits, closed seasons, bans on harvesting molting or berried lobsters, and restrictions on the use of impaling gear (DuBois, 1985; Mahon, 1987). In 1984, the OECS initiated the process of harmonizing regulations for lobster fishing. These regulations included the above measures, with one size limit for all islands. The implementation of these regulations is at various stages in various islands. The degree of enforcement of the past or harmonised regulations varies considerably among islands.

3.1.2 Stock structure, migration, dispersal

The stock structure of spiny lobsters in the west central Atlantic continues to be an unresolved problem. The relatively long planktonic stage, up to 6 months, for spiny lobsters makes possible the existence of a single panmictic population in the Caribbean Region. However, it is probable that the timing and location of spawning, coupled with local current patterns (eddies and gyres) result in the return of juveniles to natal areas.

structure in the Lesser Antilles. However, several Lesser Antilles islands are participating in the regional lobster recruitment study, organised through the Gulf and Caribbean Fisheries Institute, aimed at resolving some of these questions.

Lesser Antillean islands which share a common island platform (e.g., US and British Virgin Islands; Anguilla and St. Martin, St. Barthelemy; St. Eustatius and St. Kitts/Nevis; Grenada and St. Vincent and the Grenadines), probably have common stocks, as lobsters are known to undertake local seasonal migrations for spawning and feeding.

In Martinique, monthly variation in catch per unit effort of P. guttatus with depth suggests the existence of seasonal migrations related to reproduction and growth (Marfin, 1978). P. argus were observed to be moving from the bays toward the open sea in November 1976 (Clairouin, 1980).

3.1.3 Biology and ecology

Growth and mortality

Males and females attain 95% of their maximum size in seven and ten years, respectively, in the US Virgin Islands. Legal size (approximately 700 g) is reached by males in approximately two years of benthic life and by females in four years. Total mortality has been reported as 33-48 % in the US Virgin Islands where strict catch limits are enforced.

The following growth parameters have been estimated by various authors.

	Sex	L	(mm)	K	t_0	Z	Source	Locality
P. argus	Both		152.0 CL	0.432	0.11	0.413-0.651	Olsen, 1983	US Virgin Isl.
	M	64	153	0.436	0.11		Olsen & Koblic, 1975	US Virgin Isl.
	F	33	133	0.319	0.16		Olsen & Koblic, 1975	US Virgin Isl.
	M	480	190	0.250	0.60		Clairouin, 1980	Martinique
	F	397	187.6	0.234	0.56		Clairouin, 1980	Martinique
	Both		188	0.246	-0.26	1.09	Goodwin et al., 1986	St. Kitts
P. guttatus	M		79	0.443			Marfin, 1978	Martinique
			70	0.423			Marfin, 1978	Martinique

Marfin (1978) and Clairouin (1980) used modal analysis, with reference to moult frequency, and a Walford plot to estimate growth parameters. Goodwin et al., (1986) used probit analysis, and a curve fitting routine. The Caribbean Fishery Management Council Lobster Stock Assessment Workshop (CFMC, 1990) was unable to estimate growth parameters from available length-frequency data because the length intervals of 1/10" were too wide to permit modes to be distinguished, and because other assumptions of modal analysis were invalid.

In the US Virgin Islands, sexual differences in growth result in male lobsters reaching market size by the end of the second year of benthic life whereas females may take up to four years. Survivorship values ranged from 52.2% to 66.1% per year (Olsen and Koblick, 1975).

In fishing grounds of less than 10 m depth in Martinique, age class 2 represents 87% of individuals caught; at greater depths, the ages were far more evenly distributed (Clairouin, 1980). A study tagged 371 *P. argus* captured by night, with a trammel net. The rate of return was 14%. The increase of CL between two moultings (an interval of 10 weeks) was 7 mm with males and 5 mm with females (Clairouin, 1980).

Growth and reproduction of *P. guttatus* have been established on the basis of 1,469 individuals caught by trammel net from January to October off the east coast of Martinique (Marfin, 1978). The average cephalothoracic length of males (58.70 mm) is longer than that of the females (51.33 mm). L_{∞} values in the above table were estimated by the Walford method, and correspond to total lengths of 212 and 202 mm respectively. A size/age relationship was obtained by grouping the modes defined by the Bhattacharya method in pairs, as there are two moultings per annum, one in January-February and the other in August-September. The age composition of the catch was almost identical for both sexes.

The following carapace-length (CL) versus total-length (TL) relationships have been reported (lengths in mm):

P. argus			
$CL = 0.415TL - 9.977$	Males	Martinique	(Farrugio, 1975)
$CL = 0.405TL - 10.989$	Females	"	"
$CL = 0.413TL - 11.000$	Both	"	"
$TL = 4.00CL^{0.91}$	Males	"	(Clairouin, 1980)
$TL = 3.25CL^{0.97}$	Females	"	"
P. guttatus			
$CL = 0.413TL - 8.500$	Males	Martinique	(Farrugio, 1975)
$CL = 0.394TL - 7.860$	Females	"	"
$CL = 0.429TL - 11.631$	Both	"	"

The following weight-length relationships have been reported (lengths in mm).

P. argus			
$W_g = 0.00023CL^{2.69}$	Males	Martinique	(Farrugio, 1975)
$W_g = 0.00017CL^{2.73}$	Females	"	"
$W_g = 0.00020CL^{2.71}$	Both	"	"
$W_g = 0.00023CL^{2.77}$	Males	"	(Clairouin, 1980)
$W_g = 0.00021CL^{2.80}$	Females	"	"
P. guttatus			
$W_g = 0.00010CL^{2.77}$	Males	Martinique	(Farrugio, 1975)
$W_g = 0.00096CL^{2.77}$	Females	"	"
$W_g = 0.00018CL^{2.77}$	Both	"	"

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Sixty percent of the 139 P. argus caught in the trammel net, and one third of the 234 P. guttatus, were above the minimum regulation lengths, which are 220 mm and 170 mm respectively for these two species (Farrugio, 1975). The marketable fraction of P. guttatus was mainly males.

Reproduction

In Martinique, sexual maturity is attained, on average, at 2 years, 4 months for males (CL=66 mm), and 2 years, 8 months for females (CL=70 mm) (Clairouin, 1980). Reproduction of P. guttatus is spread over a considerable time, the maximum spawning period being March-May, with a secondary peak in July-August (Marfin, 1978). The sex ratio and the percentage of females bearing eggs vary during the year. Spiny lobsters move to the shelf edge to spawn.

Evidence of the relative importance of larger females in contributing to population reproductive potential, and the relatively poor contribution of smaller, newly mature females have been found in St. Kitts (Goodwin et al., 1986). Farrugio (1976), who also found that sex ratio varied throughout the year in Martinique, provides data on fecundity of lobster at various sizes but does not calculate a relationship. The observed range was 17,568-68,984 eggs for females of 118-174 mm total length respectively. Females producing eggs for the first time in the year carried significantly more eggs than those producing eggs for the second time.

Recruitment

Artificial habitats have been used to monitor puerulus recruitment for Panulirus species. Reports from the Caribbean (Antigua and Barbuda, Puerto Rico) indicate year-round recruitment of P. argus with greatest influx in late summer-early fall and a smaller peak in spring. In Le Robert Bay, Martinique, post larvae of P. argus were available all year, with maxima in May and August (Coton and Nijean, 1987). The majority of post larvae belonged to stages 1 and 2.

Lobster juveniles are know to inhabit inshore habitats such as seagrass beds and mangrove lagoons. This was found to be the case in St. John, US Virgin Islands (Olsen et al., 1975). Most juveniles had left the mangroves by the time they were 80 mm CL.

Adult ecology

Patterns of habitation, den occupancy, and nocturnal movements of spiny lobsters, P. argus, were described from diver observations using individually identifiable back tags and sonic remote sensing techniques (Herrnkind et al., 1975). Den selectivity, long-term individual residency, characteristic multiple occupancy of dens, and homing behaviour were documented.

Population abundance was estimated in the US Virgin Islands by diver counts and mark-recapture studies. Abundance varied due to immigration and emigration, with the latter ranged from 45-90% per month (Cooper et al., 1975).

3.1.4 Stock assessment

Exploratory fishing

Experimental lobster fishing in the Lesser Antilles by the FAO/UNDP Caribbean Fishery Development Project was confined to the northern Leeward Islands (Chislett and Yesaki, 1974). The pots used were identical to commercial lobster pots in Nicaragua: 2' x 2' x 1' with 1" x 2" galvanized rectangular mesh and a woven wicker funnel set in a 1 sq. ft opening in the side. Thirty-four strings comprising 1,055 pots set at depths of 9-150 fathoms in the vicinity of Anguilla, Saba, Barbuda banks and other small banks in the area caught three lobsters. In the same area, 26 and 6 hauls with Z and D traps respectively caught no lobsters but yielded fair catches of snappers and groupers. These results were considered surprising considering previous estimates of abundant lobster resources in the Northern Leeward Islands specifically on the Barbuda and Anguilla Banks.

A survey with trammel nets on the Atlantic continental shelf of Martinique (October 1974 - July 1975), from the coast to depths of 50 m took 56 fish species and 9 crustaceans, over 5 types of substrate (Farrugio and Saint-Felix, 1975). The catches (kg/100 m of net) were practically nil at less than 5 m, and of the order of 5 kg at depths of 10-50 m. Lobster represented 21% of the catch with yields of between 0.1 and 3.4 kg/100 m. P. guttatus is most abundant on hard beds below 5 m whereas the best yields of P. argus are found on plant-covered and decayed coral beds, at depths of 10-26 m. Bearing in mind the selectivity of the trammel nets used, 60% of the P. argus caught were larger than the minimum regulation size of 22 cm. These individuals were usually found deeper than 10 m.

Length and weight distributions

Monitoring of length frequency distributions and average weight of individuals in the catch has been one of the predominant means of evaluating the status of lobster stocks in the Caribbean.

The size and weight distribution of spiny lobsters sampled in the US Virgin Islands in 1981 is shown in Table 3 (Castilo-Barahona, 1981). The results of this survey were compared to those of a similar study conducted in 1978/79 (CFMC, 1981) (Table 4). An overall decline in both average carapace length and average weight is apparent, suggesting possible overexploitation of the resource.

Bohnsack et al. (1990) present length frequencies for landed lobsters in several categories -- males, females with eggs, females with tar spots, females without tar spots -- from the US Virgin Islands. They compare the lengths of these lobsters with the lengths from a heavily fished lobster stock in Florida and an unfished stock in the Dry Tortugas, and found that lobsters from all areas of the US Virgin Islands were larger than those in the former area. Lobster from St. Croix tended to be smaller than those from the Dry Tortugas, whereas in St. Thomas/St. John, there was a higher proportion of large lobster.

Potential yield

Rough estimates of potential yield from island shelves in the Lesser Antilles are based on a figure of 0.05 t/km^2 (Olsen, 1983) of shelf area within the 200 m depth contour (Mahon, 1990c) (Table 2). This figure requires a number of assumptions, for example that 40% of the shelf is suitable lobster habitat. Clearly this varies considerably from one island to another, as will other factors influencing yield. Therefore, although the estimates may be useful as a guide to the likely value of the resource to the region, they are too rough to be used for island specific management.

3.1.5 Future directions

In theory, lobster management could be based on any of the standard assessment techniques. Some of these could be applied in the near future, others would require considerable research. Which of these can and should be used depends on what can be enforced and the amount of money allocated for management. Some of the input parameters for yield/recruit models are available from the Lesser Antilles. These include growth parameters, natural mortality and recruitment pattern to the fishery. The lobster fishery may be sufficiently valuable to warrant investing the effort required to estimate these parameters.

The possibility of applying the spatial variation of the general production model to estimate potential yields from island platforms could be considered. The problems of this approach are discussed by Mahon (1990c) in connection with demersal fishes, and in Section 3.3.5 of this report. Similar arguments apply for lobster, except that there are far fewer species.

Juvenile lobsters inhabit inshore habitats such as seagrass beds and mangrove lagoons. It is accepted that degradation or loss of coastal habitats can negatively impact recruitment of lobsters to the fishery. Lobster management therefore requires that these 'critical' habitats be protected. These habitats are usually threatened by tourist and urban coastal development.

Table 3. The size and weight distribution of spiny lobsters ampled in the US Virgin Islands (Castillo-Barahona, 1981)

	St. Thomas-St. John		St. Croix	
	(June 1978)		(July 1978)	
Size (inches)	No. lobsters	Pounds	No. lobsters	Pounds
3.0 - 3.2	14	23.25	1	3.5
3.25 - 3.4	-	-	-	-
3.5 - 3.9	26	52.75	17	31.5
4.0 - 4.4	36	88.0	85	182.37
4.5 - 4.9	35	95.5	68	170.25
5.0 - 5.4	27	91.25	48	155.0
5.5 - 5.9	7	26.25	12	44.75
6.0 - 6.4	1	4.75	1	4.75
6.5 - 6.9	-	-	1	5.4
Total	146	381	233	596.12
Avg. carapace length (in)	4.40	-	4.6	-
Avg. weight	-	2.61	-	2.55

Table 4. Comparison of lobster size frequency between 1980/81 and 1978/79, in the US Virgin Islands

Item	1978/79	1980/81
Average carapace length (inches)		
St. Thomas-St. John	4.40	4.44
St. Croix	4.60	4.30
Average weight (pounds)		
St. Thomas-St. John	2.61	2.80
St. Croix	2.55	2.49
Percent of lobsters below 3.5" C.L.		
St. Thomas-St. John	9.6	7.9
St. Croix	0.4	15.6

The figures for St. Thomas-St. John are June 1978 versus June 1981 and for St. Croix, July 1978 versus July 1981.

3.2 Conch

3.2.1 Overview of the fishery

Conch are sedentary and aggregate in specific habitats, where they are easily exploited by divers. Most of the catch is sold to restaurants, or exported. Martinique and Guadeloupe are primary export markets. Consequently, the queen conch is severely depleted throughout the Lesser Antilles (FAO, 1985; Appeldoorn et al., 1987), and was one of the first species to be considered as overexploited. In 1960s overexploitation was already evident on the Grenada Bank, although boats were not yet mechanized (Adams, 1970).

Conch is probably the second most valuable fishery resource in the Lesser Antilles. A rough (order of magnitude) estimate of 1,300 mt/year for the potential yield of conch from the island shelves of the Lesser Antilles (see Section 3.1.1), allows a preliminary estimate of the value of this resource to the region. Assuming an export value of about US$ 6.00/kg, this yield would be worth about US$ 7-8 million. Retailed to tourists in restaurants at about US$ 10.00 per 200 g meal, this annual conch yield would be worth about US$ 40 million, most of which would be in foreign currency earnings.

Conch are harvested primarily by free diving in shallow waters, and SCUBA diving in deeper water. In some areas divers routinely work at depths over 100 ft. In certain islands, for example the British Virgin Islands, an appreciable proportion of the catch is taken by recreational divers. In general, for those islands where conch is a significant part of the catch, fishing tends to be pursued from only a few landing areas.

Until recently, conch management in the Lesser Antilles consisted of a variety of regulations enacted or proposed to reduce fishing pressure. These include a minimum size limit on shell length, shell diameter, lip thickness, or meat weight, and seasonal closures (Mahon, 1987; CFMC, 1988). In 1984, the OECS initiated the process of harmonizing regulations for conch fishing. These regulations are primarily a minimum size limit of 18 cm shell length and 225 g market weight, the presence of a thickened shell lip, and the prohibition of SCUBA fishing for conch on all islands. The process of bringing these regulations into effect is in various stages in various islands and their enforcement varies considerably among islands. There are no data from which to evaluate whether these regulations are reducing overexploitation and promoting rehabilitation of the resource.

3.2.2 Stock structure, migration, dispersal

Queen conchs (Strombus gigas) occur throughout the Caribbean, southern Mexico, Florida Keys, Turks and Caicos Islands, Bahamas and Bermuda, but are not found south of the Orinoco River. Although the stock structure of queen conch in the Caribbean region is unknown, circulation patterns within the Caribbean and the duration of the planktonic phase indicate that downstream transport and/or retention of larvae are possible. Within the eastern Caribbean, it is likely that larvae from throughout the region combine to form a mixed pool of larvae, which could recruit over an equally broad region. Electrophoretic analysis of gene frequencies from various populations found no fixed allele differences between areas. Eastern Caribbean populations showed differences from those in Belize and Turks and Caicos, indicating that there may be a separate southeastern Caribbean conch stock (Berg et al., 1986). However, differences were also found between populations from the north and south coasts of St. Lucia, thus interpretation of these differences is unclear.

3.2.3 Biology and ecology

There have only been a few studies on the biology and ecology of conch in the Lesser Antilles, although there are several relevant studies from other areas of the Caribbean. These are reviewed by Appeldoorn et al. (1987).

Growth and mortality

At sexual maturation, growth in shell length of queen conch ceases, and the characteristic flared-lip is produced. This has been estimated as taking place between 2.3 and 2.8 years of age in St. Kitts (Wilkins et al., 1987) and at age 3 in St. John, US Virgin Islands (Berg, 1976). Conch shell weight and flesh weight continue to increase after the flared-lip is formed. Lip thickness increases considerably, and the lip can be used for aging. Growth in flesh weight occurs to a lesser degree than that of the shell weight. In St. Kitts, a 35% increase in weight took place in one year after lip formation.

Conch growth was examined by observing tagged individuals over a period of about a year in St. John, US Virgin Islands (Randal, 1964). However, growth parameters have never been estimated from these data. Berg (1976) estimated the following Von Bertalanffy parameters for growth in shell length of conch in the US Virgin Islands: St. John, $L_\infty = 260.4$ mm, $K = 0.516$; St. Croix, $L_\infty = 241.7$ mm, $K = 0.420$.

The following lengths at age (mm) have been observed or calculated for queen conch at various locations in the Lesser Antilles.

Age (years) 1	2	3	Location	Source
108	170	205	St. John, U.S.V.I.	Berg, 1976
90	126	157	St. Thomas, U.S.V.I.	Wood & Olsen, 1982
100	155	225	St. Kitts/Nevis	Wilkins et al., 1987

On the basis of growth rates, longevity is estimated to be six years in the US Virgin Islands. Instantaneous natural mortality rates (M) have been shown to decrease with age such that adult conch can be expected to have a natural mortality rate of 0.8 or an annual survival rate of 45%. In St. John, M values ranged between 3.52 and 1.92 for conch between ages 1 and 2 (Appeldoorn et al., 1987).

Reproduction

Hydrolab studies of a US Virgin Islands conch population which had been unfished since 1978, indicated seasonal migration to deeper water in winter down to 50 m, and suggested that stocks of conch in deep water may play a significant role as a spawning reserve (Coulston et al., 1987). Copulation and egg-laying appeared to occur in two periods each year: February-March and November-December in St. John, US Virgin Islands; and pre-July and late September in St. Thomas. Females took 24-36 hours to lay their egg masses, which contained 300,000-700,000 eggs (Randall, 1964).

Adult ecology

Wood and Olsen (1982) found the following distribution of conch in various habitat types in the US Virgin Islands (StT = St. Thomas, StJ = St. John, StX = St. Croix):

	Algal Plain		Coral		Sand		Grass	
Terrain	StT-StJ	StX	StT-StJ	StX	StT-StJ	StX	StT-StJ	StX
No. of transects	36	27	22	19	21	24	23	12
Area surveyed(ha)	9.8	7.3	3.8	4.7	3.3	3.2	4.3	2.6
Density (conch/ha)	9.31	10.15	10.58	7.79	9.31	5.76	6.47	2.40
Standard deviation	9.65	8.88	10.34	6.24	6.32	4.20	7.37	3.17

3.2.4 Stock assessment

One of the main impediments to evaluating the status of conch resources in the Lesser Antilles is a lack of data on landings, effort and the size of individuals in the catch. There are several aspects of conch biology which complicate the application of standard assessment techniques to this species (Appeldoorn, 1987). However, some assessment techniques could presently be applied, if due consideration is given to the implications of probable errors in input parameters. Other techniques would require considerable research. Which of these can and should be used depends on what can be enforced and the amount of money allocated for management.

Whereas it is evident that growth overfishing has taken place in most areas, and there is circumstantial cause for concern about recruitment overfishing, there is no hard evidence that the recruitment potential of the resource has been affected by the depletion which has taken place. However, Appeldoorn (in press a) argues, on the basis of the reproductive characteristics of conch, that there may be a critical stock density for successful reproduction of conch.

The most extensive assessments of queen conch in the Lesser Antilles have been in the US Virgin islands (Appeldoorn, 1992). These include estimates of natural and fishing mortality, yield per recruit analyses, and maximum sustainable yield estimates by general production modelling and by the product of yield per recruit and recruitment estimates.

Potential yield

Even approximate information on potential yield versus actual yield could be used as a guide to management. Estimates of conch MSY from the Bahamas, US Virgin Islands and Puerto Rico range from 0.03-0.1 mt/km^2/yr (Appeldoorn, 1992). The value for the US Virgin Islands (0.06 mt/km^2/yr) has been applied to the island shelves and shallow banks of the Lesser Antilles (Mahon, 1990c) to provide a very rough (order of magnitude) estimate of 1,300 mt/yr for the potential yield of conch from the entire Lesser Antilles (Table 2).

3.2.5 Future directions

With due consideration to the aspects of conch biology described by Appeldoorn (1987), estimation of potential yield and appropriate levels of exploitation could be based on refined yield per recruit estimates, and surveys of the density of recruits.

Degradation or loss of seagrass and other inshore juvenile habitats would be expected to negatively impact recruitment of conchs to the fishery. Conch management therefore requires that these 'critical' habitats be protected. These habitats are usually threatened by tourist and urban coastal development. Resolution of these conflicts among different economic sectors is beyond the scope of a fishery management plan and should be pursued in the context of a coastal development plan.

3.3 Demersal Resources of Island Shelves, Slopes and Banks

3.3.1 Overview of the fishery

The fisheries operating on the island shelves, in reef and related habitats are generally considered as separate from those on the slopes of island platforms, and on the deeper banks. This distinction is a convenience which is based more on the gear used than on the discreteness of the resources, which are distributed continuously along the depth gradient.

Fisheries for finfish in reef and associated habitats are among the most economically important in the Lesser Antilles, as they provide relatively cheap protein and employ the majority of fishermen. Traps and handlines are the main gear for reef fishes, although trammel nets are common in Martinique, and longlines (palangres) are used in several islands. These gears typically target numerous species simultaneously. All species of fishes large enough to be retained by the meshes of the traps are caught and utilised. The species composition of the catch varies among habitats and with the degree of exploitation. In areas which have not been overexploited, snappers, groupers, and large parrotfishes may contribute significantly to the catch. In heavily exploited areas, such as Barbados (Wilson, 1983) only a few families contribute most of the catch (squirrelfishes, grunts, surgeonfishes).

The fisheries for reef fish species are typically artisanal with the catch landed at a large number of sites and consumed locally. The fishermen are often part-time. Since most island shelves are narrow, fishing trip distances are short and the boats are small (4-8 m), open and outboard engine powered (8-48 hp). In some islands with large shelf areas (Antigua/Barbuda, Grenada) larger, inboard powered sloops are also used. The characteristics of the fleets, types of gear, fishing practices, and distribution patterns for most of the Lesser Antilles (except, French, Netherlands, and US Virgin Islands), are described by Mahon and Rosenberg (1988) and other references cited in Section 2.4).

Despite the apparent undeveloped nature of the fishery, it is widely accepted that reef fish resources are overexploited. The evidence is the absence of large individuals from the catch, the scarcity of some of the larger species (e.g., snappers, groupers, parrotfishes) from the catch and an acknowledged reduction in abundance on traditional fishing grounds. The degree of exploitation may vary from one area to another on the same island platform, with the resources near shore and near centres of population being most depleted. For example, Olsen (1984) concluded that the shallow reef-fish resources in the vicinity of St. Kitts were probably overexploited, but that those in the vicinity of Nevis might not be.

The fisheries operating on the slopes of island platforms, and on the deeper banks are also typically trap and handline, as well as trammel nets in Martinique, and occasionally longlines, but tend to be pursued from larger boats than those used for reef fish fisheries. These boats are usually also better equipped with depth sounder and trap haulers. The catch in these fisheries tends to consist primarily of large, "quality" fishes, which are sold to processors, restaurants, or exported directly. Appeldoorn et al. (1987) provide a comprehensive review of the fisheries for, and the biology and assessment of these resources. The little work which has been done on these resources in the Lesser Antilles, is mostly from the US Virgin Islands.

Commercially exploited snappers and groupers from the Lesser Antilles, Virgin Islands and Puerto Rico are listed in Table 5.

Table 5. List of commercial snappers and groupers from the Lesser Antilles, Virgin Islands, and Puerto Rico and their respective fishery (D = deep water, S = shallow water) (Appeldoorn et al., 1987)

Species	Fishery	Common names
Serrenidae		groupere
Aiphestes afer	S	mutton hamlet, varech, guasete (aceituna)
Cephelopholis cruentete	S	graysby, cone essaim, cherna enjambre
Cephalopholis fulva	S	coney (butterfieh), cone ouatelibi, cherna cebrilla (guativere)
Dermatolepis inermis	D	marbled grouper, meran marbre, mero marmol
Epinephelus adscensionie	S	rock hind, merou oualioua, mero cabrille (cebre more)
Epinephelus flevolimbatue	D	yellowedge grouper, merou eile jaune, mero aletae amarille
Epinephelus guttatus	S	red hind, merou couronne, mero colorado (cabrille)
Epinephelus itejere	S	jewfish (june fieh), merou geant, mero guasa
Epinephelus morio	D	red grouper, merou rouge, mero americano
Epinephelus mystacinus	D	miaty grouper, merou brouillerd, mero lietado (cherna de lo elto)
Epinephelus nigritus	D	wereew grouper, merou poloneie, mero negro
Epinephelus niveatus	D	snowy grouper, merou neige, cherna pintada
Epinephelus etriatus	S	Naeaau grouper (hamlet), merou raye, cherna criolla
Mycteroperce bonaci	S	black grouper, badeche bonaci, cuna bonaci (eguaji)
Mycteroperca cidi	S	white grouper, badeche blanche, cuna blance
Mycteroperca interatitialia	D	yallowmouth grouper, badeche gueule jaune, cuna amarilla (abadejo)
Mycteroperca rubra	S	comb grouper, badeche peigne, cuna negre
Mycteroperca tigris	S	tiger grouper, badeche tigre, cuna gete
Mycteroperca venenosa	D	yellowfin grouper, badeche de roche, cuna de piedre (arigua)
Lutjanidae		snappere
Apsilus dentatus	D	black snapper, vivaneeu noir, pargo muleto (chopa negre)
Etelia oculatua	D	queen snapper, vivaneau royal, pargo cechucho
Lutjanus enalia	S	mutton snapper, vivaneau aorbe, pargo criollo
Lutjanus apodus	S	echoolmaater, vivaneau dentchien, pargo amarillo (ceji)
Lutjanus buccanella	D	bleckfin snapper, vivaneeu oreille noire, pargo eesi
Lutjanus cyanopterue	S	cubera snapper, vivaneau cubera, pargo cubere
Lutjanus griseus	S	gray enapper (mangrove snapper), viveneeu serde griee, pargo prieto (cabellerote)
Lutjanus jocu	S	dog snapper, vivaneau chien, pargo jocu
Lutjanus mahogoni	S	mahogany snapper, vivaneeu voyeur, pargo ojon (ojenco)
Lutjanus purpureus	D	Caribbean red enapper, vivaneau rouge, pargo colorado
Lutjanus eynagrie	S	lane enapper, viveneau gazou, pargo biajaiba
Lutjanus vivanus	D	ailk anapper, vivaneau aoi, pargo de lo alto
Ocyurus chrysurus	S	yellowtail snapper, vivenee queue jaune, rabirrubie
Pristipomoidee macrophthelmus	D	vorez snapper, colaa gros yeux, panchito ojon
Rhomboplites aurorubens	D	vermilion enapper, vivaneau ti- yuex, pargo cunaro (cagon)

Most of the information on the species composition of snapper-snapper-grouper assemblages in deep waters of the Lesser Antilles comes from exploratory fishing (see Section 3.3.4). In the Lesser Antilles the deep-water catch is primarily composed of silk snapper, blackfin snapper, and misty grouper. Blackfin snapper are most abundant between 55 and 95 m (30 to 50 fm), whereas silk snapper are more abundant deeper, from 165 to 210 m (90 to 115 fm). Other species, such as vermillion or black snapper, may occasionally be taken in large numbers, but rarely make up more than 1% of the catch. In Barbados, the deep slope is fished with traps and handlines which tend to catch different species. Silk snapper predominate in the traps, while queen and vermillion snappers predominate on handlines (Prescod, 1991).

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In contrast to reef fish resources of the island shelves, deep slope and bank resources are considered to be underexploited. Nonetheless, total yields from these resources are relatively small (Table 2). Therefore, any rapid expansion of fishing effort on these resources may quickly overexploit them. In several islands there have been recent increases in fishing effort directed at these resources.

Ciguatera poisoning is an important concern in demersal fisheries, but least so for the deep-water species. However, it is essentially absent south of Martinque. Further details of the species which are known to be ciguatoxic are given in Section 3.3.3.

With the exception of minimum size limits in the US Virgin Islands (CFMC, 1985), there are no regulations currently controlling the exploitation of demersal fishes of the island shelves, slopes and banks in the eastern Caribbean, although trap mesh size regulations are being widely considered. The use of dynamite is prohibited but this regulation is not widely enforced.

3.3.2 Stock structure, migration, dispersal

There is virtually no information on the stock structure, migration and dispersal of demersal fishes in the Lesser Antilles. All the exploited demersal fishes have planktonic early life history stages, but the question of whether extensive dispersal takes place during this period, or whether the time and place of spawning is selected to maximise return of recruits to parent populations remains unresolved. Once they have settled, reef fishes remain in association with the substrate, and are sedentary. Therefore, exchange of demersal juveniles and adults between island shelves is probably negligible.

The Expert Consultation on Shared Fishery Resources of the Lesser Antilles concluded that, in one-country-per-shelf situations, independent management could be undertaken with reference to local socio-economic requirements. However, given the possibility of larval exchange, spawning stock biomass levels should be maintained. In shared shelf situations demersal stocks are probably transboundary, and co-operative management was recommended (Mahon, 1987).

Spawning aggregations, which will be discussed in Section 3.3.4 below, may result from migrations of several kilometers. These aggregations are particularly susceptible to overexploitation, and may present a special transboundary migration situation on shared shelves, in which a critical habitat, or requirement for reproduction, is present in only one state.

3.3.3 Biology and ecology

There has been a variety of research on reef fishes and reef fish assemblages in various parts of the Lesser Antilles and a list of species is shown in Table 5. Although these studies have not been oriented towards solving fishery problems, they provide a significant body of background information on the production system, and are briefly reviewed below.

Growth and mortality

Information on the growth and mortality of demersal species is scant. The following parameters have been estimated:

Species	L_{∞} (mm)		K	t_0	M	F	Z	Source
Nausau grouper (Epinephelus striatus)	974(SL)	0.183	0.488	0.364	0.916	1.280		(Olsen, 1983)
Queen snapper (Etelis oculatus)		102(TL)	0.4	-0.294			1.873	(Murray and Moore, in press b)
Red hind (Epinephelus guttatus)	601(FL)	0.071	-4.69	0.16	0.17	0.33		Sadovy and Figuerola (in press)

Randall (1962) tagged reef fishes at five sites in Lameshur Bay, St. John, US Virgin Islands, and recorded growth increments of recaptured individuals (Table 6).

Table 6. Species, sample sizes, and size ranges of reef fishes tagged in St. John, US Virgin Islands (compiled from Randall, 1962)

Species	N	Size range (mm)
Acanthurus bahianus	21	97-180
A. chirurgus	10	86-181
A. coeruleus	19	93-190
Balistes vetula	10	192-302
Holocanthus ciliaris	7	186-217
Pomacanthus aureus	8	144-280
Holocentrus ascensionis	11	137-213
H. rufus	15	162-206
Lutjanus apodus	7	152-329
L. griseus	3	152-180
Ocyurus crysurus	6	121-193
Haemulon plumieri	8	150-263
H. sciurus	4	143-215
Scarus coeruleus	4	188-313
S. vetula	3	140-248
Sparisoma crysopterum	3	155-182
S. rubripinne	9	175-266
S. viride	3	187-236
Cephalopholis fulva	20	188-295
Epinephelus adscensionis	6	217-379
E. guttatus	15	213-304
E. striatus	40	175-451
Mycteroperca tigris	6	324-482
Mycteroperca venenosa	25	295-505
Petrometopon cruentatum	3	269-289

Length-frequency distribution for silk, blackfin and voraz snappers as well as seasonal abundance and areal distribution were studied in the Virgin Islands (Sylvester, 1974). In decreasing order of abundance, these species comprised the bulk of most catches. Length-frequency comparisons indicate that silk snappers probably attain a larger size than blackfin or voraz snappers. Length-frequency data for eight species from the US Virgin Islands fishery, primarily yellowtail snapper, queen triggerfish, red hind, and Nassau grouper, are presented by Morales-Santana (1984)

Growth and mortality data indicate the presence of six age classes in silk snappers, with adults reaching an asymptotic maximum size of 117 cm. (Sylvester _et al._, 1980). Recruitment to the adult population occurs during the first two years of life, probably from a different juvenile habitat.

Most growth studies have used length frequency data. However, daily growth rings in otoliths have been used for _Haemulon plumieri_ in Martinique (Chevaillier, 1990) and for _Etelis oculatus_ in St.Lucia (Murray and Moore, in press b).

Feeding

In an extensive study of the feeding habits of reef fishes in the US Virgin Islands, Randall (1967) analysed the stomach contents of 5,526 individuals of 212 species, and described seven feeding categories. Feeding has been studied in more detail for _Pempheris schomburgki_ and squirrelfishes (Gladfelter, 1979; Gladfelter and Johnson, 1983). Three quarters of stomachs from silk (n=141) and blackfin (n=39) snappers in the US Virgin Islands were empty or everted. Of those with food, 52% by volume in silks and 48% in blackfins was fish (Sylvester _et al._, 1980).

Recruitment

The patterns of settlement of juvenile reef fishes from the plankton to demersal habitats has been the subject of considerable recent study. Some of the research on recruitment of reef fishes in the US Virgin Islands has been on commercially exploited species, such as French grunts, ocean surgeonfish and mahogany snapper (McFarland _et al._, 1983; Shulman, 1985a; Shulman, 1985b). This has shown a high degree of temporal variability on monthly, seasonal and interannual time-scales. In the case of French grunts there was settlement year-round, with two distinct maxima during May-June and October-November. This is consistent with the seasonal variation in catches of planktonic larvae of reef fishes off Barbados (Powles, 1975). Murray and Moore (in press a), and Murray _et al._ (1992) note that there appear to be two recruitment peaks a year for queen snapper, _Etelis ocelatus_.

Studies on the factors affecting the recruitment of juveniles to reefs in the US Virgin Islands have found that settlement and survivorship of juveniles may be affected by complex interactions with other reef organisms, including other recently settled reef fish juveniles, and predators (Shulman _et al._, 1983; Shulman, 1985a; Shulman, 1985b).

Studies in the Lesser Antilles region support the view that seagrass beds and mangrove lagoons are nursery habitats for several species of demersal fishes (Lasserre and Toffart, 1977). Production of juvenile *Ocyurus crysurus* in a *Thalassia* bed in Guadeloupe was found to be 5.6 g/m^2/yr (Baelde and Louis, 1987). In mangrove lagoons in Guadeloupe, 70% of species were represented only by juveniles (Louis and Laserre, 1982; Louis and Guyard, 1982).

Reef fish assemblage structure

Studies of reef fish assemblages in the Lesser Antilles have been primarily descriptions of species composition and relative abundance. Such data are available for reef and related habitats around Anegada (Dunne and Brown, 1979), St. Lucia (CEHI, 1990), Anguilla (Oxenford and Hunte, 1990), and for a fringing reef on the west coast of Barbados (Miller, 1975).

Other studies have examined the role of space in determining assemblage structure (Smith and Tyler, 1972; Shulman, 1985c), and have addressed the the relative importance of stochastic and deterministic processes (Gladfelter and Gladfelter, 1978; Gladfelter *et al.*, 1980; Ogden and Ebersole, 1981).

Ciguatera

Ciguatera poisoning continues to be a serious impediment to development of demersal fisheries in the northern Lesser Antilles (Table 7). Distribution of ciguatera in the Lesser Antilles indicates that it occurs most frequently north of Martinique (Olsen and Wood, 1983). The risk of intoxication varies considerably among commonly caught species of fishes (Table 8).

Ciguatera has a long and continuing history in the US Virgin Islands (Sylvester *et al.*, 1977). There is much folklore about its origin, transmission and treatment. In St. Thomas, nearly 50% of the 84 species in the catch and 56% of the total landings by weight bear some risk of intoxication (Olsen and Wood, 1983). The annual incidence of ciguatera fish poisoning may reach 9% in Caribbean Communities like St. Thomas, US Virgin Islands.

Davin *et al.* (1978) studied the incidence of toxicity among fishes collected in the eastern British Virgin Islands (Table 9). Some of his conclusions are: the 100 fathom drop-off is in some way involved in the occurrence of ciguatera in the British Virgin Islands; the water on the windward side of unprotected islands is more likely to have toxic fish than the leeward side; there does not appear to be a correlation between the size of the fish or the depth of its capture (within the scope of this study) and its toxicity; the highest concentrations of ciguatoxic fish in the eastern half of the British Virgin Islands are located in the waters near the south tip of Anegada Reef, Seal Dog rocks, south east tip of Norman Island, and around Virgin Gorda Island at Pajoros Point, South Sound Bluff, Copper Mine Point, and Colesan Point. Biotests, using mosquitos and chicks were carried out on exploited demersal fishes from the Anguilla platform, particularly in the area of St. Martin and St. Barthelemey toxicity of species tabulated (Lorance, 1988).

Table 7. Western Atlantic fishes reported to be occasionally to frequently ciguatoxic. The species are presented in phylogenetic order, and common names are based on FAO nomenclature (De Sylva and Higman, 1980)

Albula vulpes, bonefish
Harengula humeralis, redear sardine
Opisthonema oglinum, Atlantic thread herring
Gymnothorax moringa, spotted moray
Lycodontis funebris, green moray
Ophichthus ocellatus, pale-spotted eel
O. ophis, spotted snake eel
Strongylura caribbaea, needlefish
Hemiramphus brasiliensis, ballyhoo
Hyporamphus unifasciatus, halfbeak
Acanthurus chirurgus, surgeonfish
Alectis crinitus, African pompano
Caranx bartholomaei, yellow jack
C. crysos, blue runner
C. fasciatus, segundo
C. hippos, crevalle jack
C. latus, horse-eye jack
C. lugubris, black jack
C. ruber, bar jack
Elagatis bipinnulatus, rainbow runner
Selar crumenophthalmus, bigeye scad
Selene setapinnis, Atlantic moonfish
S. vomer, Atlantic lookdown
Seriola dumerili, greater amberjack
S. rivoliana, almaco jack
Trachinotus falcatus, permit
Uraspis secunda, cottonmouth jack
Coryphaena hippurus, dolphin
Bodianus rufus, Spanish hogfish
Lachnolaimus maximus, hogfish
Lutjanus apodus, schoolmaster
L. buccanella, blackfin snapper
L. cyanopterus, cubera snapper
L. jocu, dog snapper
L. vivanus, silk snapper
L. aya, red snapper
Ocyurus chrysurus yellowtail
Scarus croicensis, striped parrotfish
S. vetula, green parrotfish
S. coeruleus, blue parrotfish
S. guacamaia, rainbow parrotfish
Sparisonma viride, stoplight parrotfish
Scomberomorus cavalla, king mackerel
S. regalis, cero
Cephalopholis fulvus, coney
Epinephelus adscensionis, rock hind
E. guttatus, red hind
E. morio, red grouper
E. nigritus, misty grouper
Myctoperca bonaci, black grouper
M. tigris, tiger grouper
M. venenosa, yellowfin
Paranthias furcifer, creolefish
Rypticus saponaceus, soapfish
Calamus calamus, saucereye porgy
Sphyraena barracuda, great barracuda
S. guachancho, guaguanche
S. picudilla, southern sennet
Alutera monoceros, unicorn filefish
A. schoepfi, orange filefish
A. scripta, scrawled filefish
Balistes vetula, queen triggerfish
Lactophrys trigonus, buffalo trunkfish
Balistes capriscus, triggerfish
Canthidermis sobaco, triggerfish
Stephanolepis hispidus, planehead filefish
S. setifer, pygmy filefish
Opsanus pardus, leopard toadfish
O. tau, oyster toadfish

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Table 8. Composition of Virgin Islands commercial fish catch in percent of pound landed and risk of ciguatera (Olsen *et al.*, 1983).

Species	Risk rank[1]	% of landings[2]
Dasayatis americana - southern stingray	4	-
Ginglymostoma cirratum - nurse shark	4	-
Tylosurus crocodilus - gar (houndfish)	3	0.45
Holocentrus adscensionis - longjaw squirrelfish	3	-
Adioryx coruscus - reef squirrelfish	3	-
H. rufus - squirrelfish	3	-
Alphestes afer - mutton hamlet	4	0.60
Cephalopholis fulva - coney	4	2.37
Epinephelus adscensionis - rock hind	2	2.31
E. guttatus - red hind	3	8.71
E. striatus - Nassau grouper	4	2.25
E. morio - red grouper	2	0.84
Mycteroperca venenosa - yellowfin grouper	2	0.58
Hypoplectrus nigricans - black hamlet	4	0.60
Petrometopon creuntatum - graysby	3	-
Seriola dumerili - amberjack	1	-
Caranx latus - horse-eye jack	1	0.37
C. ruber - bar jack	1	0.75
C. fusus - blue runner or hardnose	3	-
C. lugubris - black jack	1	-
Scomberomorus cavalla - kingfish	2	2.34
Euthynnus alleteratus - bonito	3	3.43
Apsilus dentatus - black silk snapper	3	0.07
Lutjanus analis - mutton snapper	4	0.13
L. apodus - schoolmaster	2	0.28
L. campechanus - red snapper	3	-
L. synagris - lane snapper	4	0.03
L. griseus - gray snapper	3	0.76
L. jocu - dog snapper	1	0.45
L. buccanella - blackfin snapper	2	0.81
L. mahogoni - mahogony snapper	2	-
Ocyurus chrysurus - yellowtail snapper	4	2.89
Pristipomoides aquilionaris - silk	4	1.92
Monacanthus ciliatus - fringed filefish	4	0.40
Balistes vetula - queen triggerfish	2	29.68
Lactophrys bicaudalis - spotted trunkfish	3	0.08
L. triqueter - smooth trunkfish	3	0.21
Acanthostracion polygonius - honeycomb cowfish	3	0.16
A. quadricornis - scrawled cowfish	3	0.27
Diodon holacanthus - spiny puffer	3	-
D. hystrix - porcupinefish	3	-
Equetus lanceolatus - jack-knife fish	4	-
E. punctatus - spotted drum	4	-
Chaetodipterus faber - spadefish	4	-
Abedufduf saxitilis - seargent major	4	-

[1] Risk rank:

Risk rank	% Landings	% Species
1. High risk of poisoning	0.37	3.5
2. Frequent poisoners	33.05	10.5
3. Infrequent poisoners	21.88	36.5
4. Seldom poisonous	44.70	49.5

[2] No figure = < 0.01%

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Table 9. The incidence of ciguatoxicity in fishes from the British Virgin Islands (Davin *et al.*, 1978)

Species	Number toxic	Number collected	Percent
Mycteroperca venenosa	2	3	66
Acanthurus bahianus	2	6	33
Holacanthus tricolor	1	4	25
Rhomboplites aurorubens	1	5	20
Acanthurus coeruleus	14	74	19
Pomancanthus arcuatus	5	30	17
Epinephelus striatus	2	12	17
Lactophrys bicaudalis	1	7	14
Scarus taeniopterus	1	8	12
Acanthurus chirurgus	5	50	10
Chaetodon striatus	3	51	6
Chaetodon capistratus	1	20	5
Acanthostacion polygonius	1	18	5
Holocenterus rufus	6	135	4
Haemulon sciurus	1	25	4
Balistes vetula	2	63	3
Pseudupeneus maculatus	1	45	2
Lactophrys triqueter	1	58	2
Calomus pennatula	1	83	1
Haemulon plumieri	1	65	1
Epinephelus guttatus	2	150	1
Lutjanus synagris	1	102	1

Table 10. Data on snappers and groupers caught in the Lesser Antilles (Zone 25 = Leeward Islands, Zone 26 = Windward islands) by exploratory fishing (Roe, 1976)

Species	Zone	Stations (No.)	Depth (m) Max	Depth (m) Min	Depth (m) Mean	Weight (kg) Max	Weight (kg) Min	Weight (kg) Mean	No. Caught
Etelis oculatus (green snapper)	25	1	463	463	-	-	-	-	-
	26	2	236	416	-	-	-	-	-
Lutjanus buccanella (blackfin snapper)	25	5	34	174	121	1.14	1.23	1.18	4
L. synagris (lane snapper)	25	2	34	40	-	0.27	0.27	-	1
L. vivanus (silk snapper)	25	7	66	174	123	0.45	1.82	1.14	6
Ocyurus chrysurus (yellowtail snapper)	25	3	23	66	42	0.05	0.05	-	1
Rhomboplites aurorubens (vermilion sn.)	25	1	35	180	-	0.23	0.45	0.27	5
Epinephelus adscensionis (rock hind)	25	2	151	174	-	0.59	0.91	0.77	3
E. flavolimbatus (yellowedge grouper)	26	1	132	132	-	4.55	4.55	-	1
E. guttatus (red hind)	25	1	36	36	-	2.73	2.73	-	1
E. morio (red grouper)	25	4	23	174	112	1.77	2.14	1.82	4
E. mystacinus (misty grouper)	25	1	174	174	-	9.09	9.09	-	1
Mycteroperca phenax (scamp)	25	1	174	174	-	1.36	1.36	-	1

Ciguatera is relatively uncommon among the species captured in deep-water fisheries. Although deep-water snappers and groupers are, on average, larger than their shallow-water counterparts only the misty grouper has a bad reputation for ciguatera poisoning.

3.3.4 Stock assessment

Exploratory fishing

Twenty-five years of exploratory fishing in the Caribbean Sea and adjacent waters were summarised by Roe (1976). The data were collected on US research cruises from 1950-1975. Two of 25 faunal zones for which data are compiled include the Leeward Islands (zone 25) and the Windward Islands (zone 26). The data for these zones are scanty (Table 10).

The UNDP/FAO Caribbean Fishery Development Project conducted exploratory fishing for demersal fishes using handlines and longlines (Kawaguchi, 1974b) (Tables 11 and 12), and traps (Wolf and Chislett, 1974) (Tables 13 and 14). Snappers and groupers dominated the exploratory deep-water trap fishing of the UNDP/FAO project, comprising from 43 to 92% of the catch by weight in the Lesser Antilles. CPUE was greatest from Antigua to Montserrat and from Trindad and Tobago; lowest CPUE was in the southern Lesser Antilles from Guadeloupe to Grenada including Barbados.

The results of the UNDP/FAO handline and longline exploratory fishing in the Lesser Antilles are summarized in Tables 11 and 12 (Kawaguchi, 1974). On the Virgin Island shelf, productive places were on the northeast edge of Barracuda Bank, chiefly black snapper (67%), and the shelf edge WNW of Whale Bank, chiefly silk snapper (41%), misty grouper (31%), and blackfin snapper (11%). Other varieties of fish included in the catch from this area were yellowtail, vermillion, schoolmaster, dog snapper, and volaz (deep sea wenchman).

A total of nearly 28 fishing days in three months in spring and fall in the Leeward islands caught mostly black, blackfin, and silk snappers throughout the area and season. A few vermillion and volaz snappers were taken from Sombrero and an unnamed bank, and some vermillion, yellowtail, volaz, queen, and a few mutton and dog snapper were taken from Anguilla Bank. Snappers contributed 72-99% of the total catch from Sombrero and the unnamed bank and 42-82% of the total from Anguilla Bank. The only jacks caught were black, almaco, and horse-eye. They contributed 1-6% by weight of the total catch on Sombrero and the unnamed bank and 3-17% on Anguilla Bank. Misty, red, yellowfin, and Nassau groupers and some hinds were caught on the Anguilla Bank. No yellowfin or red grouper were caught from Sombrero and the unnamed bank.

The range of daily catch rate in kg/line/hour on the different edges of the Anguilla Bank were 2.2-9.8 on the northwest edges, 0-15.0 on the north to northeast edges, 2.5-8.6 on the north edges of the eastern part, and 2.2-14.0 on the east tip. The edges of the Anguilla Bank were generally very steep, falling to more than 100 fathoms from 30 to 50 fathom edges. The

Table 11. UNDP/FAO exploratory fishing handline catch rates summarised by area (from Kawaguchi, 1974b)

	Total hours/days fished		Catch rate	Catch composition (% in weight)				
Area	(hrs)	(days)	lb/line/day	Snapper	Jack	Grouper	Grunt	Other
Leeward Islands								
Sombrero Bank	36.1	3.5	100 (114)	90.5	2.8	6.5	0	0.2
A bank SE of Sombrero	6.5	1.5	184 (156)	86.8	6.3	6.9	0	0
Anguilla Bank NW edge	8.5	1.5	76 (43)	62.0	13.0	19.3	0	5.6
Anguilla Bank N edge	35.9	4	174 (156)	64.9	12.4	22.5	0	0.2
Anguilla Bank NE edge	19.9	3.3	99 (60)	58.6	6.4	30.2	0	4.7
Anguilla Bank E edge	183.6	13.5	159 (215)	68.0	11.1	14.7	0	6.3
Anguilla Bank SE edge	10	1	59 (59)	49.7	9.5	40.8	0	0
Saba Bank	6.3	1	20 (12)	57.3	12.1	25.8	4.8	0
Barbuda bank N to NE edge	44.6	4.6	123 (118)	80.4	10.1	8.9	0.1	0.4
Barbuda Bank W edge	67.7	8	140 (118)	84.9	8.0	7.2	0	0
Barbuda Channel E edge	1.1	0.3	69 (30)	100	0	0	0	0
Antigua SE to S edge	5.9	0.6	0	0	0	0	0	0
Nevis Island SW	7.4	1	2 (2)	100	0	0	0	0
Redonda NE	2.7	0.5	97 (52)	53.4	0	46.4	0	0
A bank NE of St. Kitts	2.7	0.5	7 (4)	100	0	0	0	0
Hever's Shoal & Montserrat	25.7	3	83 (71)	84.0	11.5	4.4	0	0
Guadeloupe	6.9	6	7 (5)	72.0	15.9	6.4	0.8	2.9
Dominica	7.1	0.6	15 (10)	15.4	84.6	0	0	0
Offshore banks SE of Dominica	7.5	1.8	1 (1)	0	85.7	0	0	14.3
Total	488.1	56.8	WM: 226 (101) UM: 75 (64)					
Windward Islands								
Martinique ESE	18.0	2	3 (3)	42.2	33.3	8.9	8.9	66.7
St. Lucia	59.6	7	17 (15)	79.2	8.1	12.7	0	0
St. Vincent	3.5	1	2 (2)	33.3	0	0	0	66.7
Barbados	86.4	9	2 (2)	9.7	37.5	46.5	0.7	5.6
Traders Bank	11.0	0.5	28 (28)	30.6	67.1	2.3	0	0
Grenadines	58.6	6	5 (5)	41.2	17.2	31.9	3.3	6.0
Grenada SW	29.1	2.3	88 (88)	65.3	31.5	1.7	0.9	0.6
Total	266.3	27.6	WM: 18 (15)					

Table 12. UNDP/FAO exploratory fishing longline catch rates summarised by area (from Kawaguchi, 1974b)

Fishing ground	Month	Total set (baskets-hooks)	Depth range (fm)	Catch rate (lb/basket)	Catch by species: Snapper	Jack	Grouper	Others
St. Lucia Shelf								
N to NW side	Jsn. 1969	2 (12- 180)	30-110	2.5	3 (14)	1 (5)	2 13)	2 (9)
South side	Jan. 1969	1 18- 120)	18	0	0	0	0	0
St. Vincent Shelf								
West side	Jan. 1969	1 18- 120)	30- 40	3.3	0	0	6 (7)	5 (191
S to SE side	Jan. 1969	2 (16- 240)	30- 45	1.4	4 (161	0	6 (71	4
Grenadine Island Shelf								
S to SW of Bequia	Jan. 1969	2 110- 150)	21- 39	0.7	1 (41	0	5 (31	0
West of Quatre	Jan. 1969	1 (5- 751	17- 19	1.4	1 (41	0	2 (3)	2 (-1
NE of Sail Rock	Jan. 1969	1 (5- 75)	27	0	Lost Gear			
NE of Carriacou	Feb. 1969	1 (10- 1601	45	0	0	0	0	0
N of NE of Grenada	Feb. 1969	3 (17- 2591	17- 27	3.0	4 (24)	0	16 (271	0
S of SW of Grenada	Feb. 1969	2 (10- 154)	196-210	0.2	2 (2)	0	0	2 (2)
Barbados Shelf								
South side	Mar. 1968	10 (100-16001	42-210	1.0	2 14)	2 (16)	6 (4)	18 (80)
South side	Mar. 1969	5 (20- 300)	28- 87	4.6	8 (701	4 (20)	1 (-)	1 (21
West side	Mar. 1968	1 (10- 160)	57- 38	0.3	0	1 (31	0	0
West side	Mar. 1969	4 (16- 240)	60-195	?	0	0	0	0 (71
N to NW side	Mar. 1969	3 (12- 1801	75-255	0.3	0	0	1 (41	7 (71

Table 13. Circumstances of good, consistent trap fishing (>9 kg/haul) in the Lesser Antilles in the UNDP/FAO exploratory survey (Wolf and Chislett, 1974)

Location	Month	Year	Day(D) or night(N) Set	Pot type and mesh Size	Depth range (fms)	No. of lifts*	Lbs. per lift
Barbuda Bank (N.W. slope)	Nov.	1969	N	"O" 2"	43-52	11	21.7
Saba Bank (N. tip of N.W. slope)	Mar.	1970	N	"Z" 1½"	50-75	25	55.6
	Mar.	1970	N	"D" 2"	50-75	38	34.0
Anguilla Bank (Northern slope)	Mar.	1970	N	"Z" 1½"	44-60	12	35.1
Barbuda Bank (N. and W. slopes)	Mar.	1970	N	"D" 2"	50-65	17	30.6
Small bank (11 mi. E. of Sombrero Bank)	Jun.	1970	N	"Z" 1½"	52-86	21	20.6
Saba Bank (Northwest slope)	Sept.	1970	D	"Z" 1½"	60-82	41	32.6
	Sept.	1970	N	"Z" 1½"	60-82	48	54.7
	Sept.	1970	D	"Z" 2"	60-82	40	33.6
	Sept.	1970	N	"Z" 2"	60-82	50	37.9
Barbuda Bank (North and northwest slope)	Sept.	1970	D	"Z" 1½"	60-80	19	29.1
	Sept.	1970	N	"Z" 1½"	60-80	31	61.3
	Sept.	1970	D	"Z" 2"	60-80	19	63.7
	Sept.	1970	N	"Z" 2"	60-80	32	38.8
Saba Bank (Northwest slope)	Dec.	1970	D	"Z" 1½"	60-115	43	33.8
	Dec.	1970	N	"Z" 1½"	60-115	38	37.2
Anguilla Bank (East edge)	Dec.	1970	N	"Z" 1½"	30-55	37	31.2
Barbuda Bank (N. and N.W. slope)	Dec.	1970	D	"Z" 1½"	60-100	12	45.9
	Dec.	1970	N	"Z" 1½"	60-100	35	33.1
Saba Bank (Northwest slope)	Apr.	1971	N*	"Z" 1½"	65-80	27	54.5

* All traps in water 22 hours.

Table 14. Composition of the catch by traps in the UNDP/FAO exploratory survey (Wolf and Chislett, 1974)

General location	BFS	SS	RS	YS	VS[2]	AS[3]	H & C	AG[3]	AJ	LRF[4]	O
Barbados	26 (25)	117 (154)	0 (0)	0 (0)	0 (0)	143 (179)	0 (0)	0 (0)	63 (229)	0 (0)	8 (4)
N. Leeward Is. Banks	126 (181)	618 (695)	1 (2)	18 (32)	202 (157)	1106 (1086)	56 (83)	95 (469)	10 (69)	288 (147)	12 (53)
N. Leeward Is. Banks	958 (1478)	2982 (3010)	7 (33)	81 (121)	531 (335)	4599 (5037)	20 (29)	115 (1190)	11 (102)	73 (117)	12 (45)
N. Leeward Is. Banks	548 (1007)	2204 (2100)	1 (3)	15 (25)	233 (123)	3013 (3273)	15 (21)	105 (816)	4 (33)	64 (26)	16 (46)
N. Leeward Is. Banks	1271 (1845)	6536 (6999)	0 (0)	45 (67)	957 (626)	8815 (9624)	28 (40)	170 (1783)	250 (1062)	86 (142)	31 (23)
N. Leeward Is. Banks	1077 (1235)	2888 (3703)	0 (0)	127 (166)	185 (146)	4279 (5253)	52 (55)	103 (442)	78 (366)	133 (86)	133 (126)
St. Vincent-Barbados	111 (151)	42 (55)	2 (15)	0 (0)	2 (3)	158 (232)	2 (4)	2 (4)	15 (26)	20 (9)	1 (3)
Saba Bank	97 (164)	2856 (2843)	0 (0)	0 (0)	57 (37)	3010 (3044)	0 (0)	11 (95)	36 (220)	2.(8)	8 (36)
Gibbs Seamount	3 (12)	0 (0)	0 (0)	0 (0)	0 (0)	5 (19)	3 (10)	23 (174)	20 (75)	95 (196)	3 (10)

BFS = blackfin snapper (L. buccanella); SS = silk snapper (L. vivanus); RS = red snapper (L. purpureus); YS = yellowtail snapper (O. chrysurus); VS = vermillion snapper & wenchman; AS = all snapper (Lutjanidae); H & C = hinds & coneys; AG = all grouper (Serranidae); AJ = all jacks (Carangidae); LRF = lesser reef fishes; O = other.

[2] Vermillion snapper (Rhomboplites aurorubens); Wenchman (Pristipomoides aquilonaris).

[3] Includes fish of other snapper species in addition to those specifically identified.

[4] Grunts (Pomadasyidae); Triggerfish (Balistidae); Squirrelfish (Holocentridae); Porgies (Sparidae).

fishing was most effective where comparatively gradual slopes exist, such as the east tip or the north tip of the bank. A total of 10 nights' fishing, mostly 32 to 38 fathoms at anchorage near the east tip of the bank, produced almost the same main varieties of fish as those in daytime, but most of the yellowtail snapper and horse-eye jack were caught during night fishing. The catch rate ranged from 2.2-9.7 kg/line/hour with a total average of 6.1 kg.

A total of 13 days fishing on the Antigua/Barbuda Bank produced relatively high catch rates along the northern half of the Barbuda Bank including the offshore banks, in spite of the short distance from the coastline of Barbuda. The catches were composed of 65 to 92% snapper, 3-33% jacks, and 0-14% groupers. The snapper was mainly silk, but blackfin and black snappers were also common and a few vermillion, queen, and dog snappers were taken. Amberjack or almaco and black jacks were the only species of the jack group captured. Yellowfin, misty, red, and Nassau groupers and hinds were the common varieties of the grouper. The daily catch rate ranged from 3.9-8.7 kg/line/hour on the northeast to north edges and 3.2-13.7 kg on the west edges of Barbuda Bank.

The catch rates from the edges of the southern Leeward Islands shelves were very poor, less than 1.0 kg/line/hour except Haver's shoal and Redonda Island shelf with catch rates of 4.0-6.8 kg/line/hour. The fishes from these areas were similar to those from the northern Leeward islands except that queen snapper were common.

The catches in the Windward Islands were mostly poor, and were effectively zero in 18 of 28 fishing days. The most productive area was around the southern tip of the Grenadine Island shelf where 4.1-5.0 kg/line/hour was obtained. The catch was 65% snapper (chiefly blackfin), 32% jacks (black, green, amberjack, and horse-eye) and 3% mixed fish with grouper, grunt, and squirrelfish. A short fishing trip to the north edge of Dominica shelf caught fish (85% blackjack) at a rate of 2.4 kg/line/hour. Around the southern tip of the St. Lucia shelf, daily catch rates of 0.7-2.0 kg/line/hour (77% queen snapper) were obtained from the 75 to 150 fathom slopes. The remainder of the shelves in this area give less than 0.5 kg/line/hour.

Exploratory and experimental fishing, primarily for snappers and groupers, was conducted around the Virgin Islands from mid-1970 to September 1972 (Sylvester and Damman, 1974). The objectives were to study sources of non-ciguatoxic sub-populations, experiment with the most efficient means of deepwater fishing in the Virgin Islands, and to study the deepwater species-complex inhabiting the waters about the Virgin Islands. The depth distribution of the two most common species in the catch, Lutjanus vivanus, and L. buccanella, and of total snapper/grouper catch is shown for traps and reels in Figure 3.

More recently (1980-1984), 686 exploratory longline fishing sets at depths of 50-250 fathoms in the area of Puerto Rico and the US Virgin Islands yielded low catch rates (Nelson et al., 1985). Moderate catch rates in deep water were dominated by

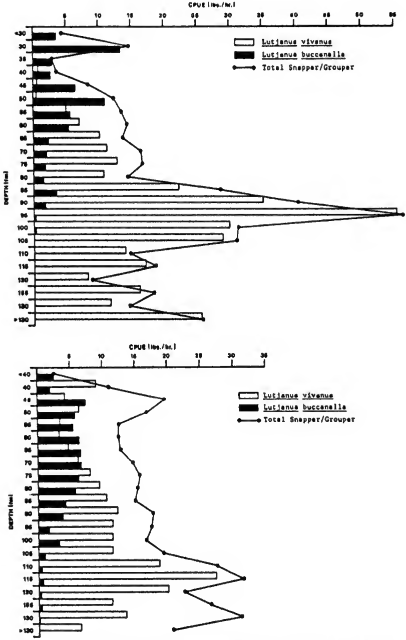

Fig. 3. Catch per unit effort of snapper and grouper by (a) traps on Saba, Anguilla and Barbuda Banks, and (b) reel fishing around the Virgin Islands (from Appeldoorn et al., 1987, based on data from Brownell and Rainey, 1971)

sharks. These depths appear to be inhabited by only a few commercial species at low density. The above observations were confirmed by a subsequent submersible survey in this area (Nelson and Appeldoorn, 1985).

The French region of the Anguilla/St. Martin/St. Barthelemey bank was surveyed using strings of five single entrance arrowhead traps and trammel nets (Lorance and Huet, 1988). The survey area was divided into eight strata on top of the bank and four strata along the drop-off, and surveyed in October-December 1986, and May 1987 (Figure 4). Trap catches are shown in Figure 5. Trammel net catches were predominantly sharks, ranging up to 75 kg/100 m of net.

A survey with trammel nets on the Atlantic continental shelf of Martinique (October 1974 - July 1975), from the coast to depths of 50 m took 56 fish species and 9 crustaceans, over 5 types of substrate (Farrugio and Saint-Felix, 1975). The catches (kg/100 m of net) were practically nil at less than 5 m, and of the order of 5 kg at depths of 10-50 m. Catches rates on various substrate types were:

Substrate	Rock	Coral	Seagrass	Rubble	Sand
Kg/unit effort	8.04	5.54	4.5	3.0	2.0

Bottom trammel nets were also used to survey depths of 100-300 m in five strata on the slope of the island shelf of Martinique from 1986-1988 (Guillou, 1989). The composition of the catch, and its bathymetric distribution are shown in Figures 6 and 7, respectively.

Although traps have been used as survey tool, they can provide only relative estimates, unless the area fished is known. Calibration of trap catches for five fish taxa in reef areas off Barbados using visual censuses, gave fished areas ranging from 135-348 m^2 per trap (Miller and Hunte, 1987).

Spawning aggregations

Spawning aggregations are common among grouper species, and are susceptible to overexploitation. Olsen and Laplace (1978) reported that the St. Thomas spawning aggregation of Nassau groupers and red hinds had been under increasingly intense fishing pressure for the previous 10 years. No catch data are available prior to 1966 but fishermen's accounts do provide some information. A decline in catch reportedly began with the 1973-74 season. Fishing methods used during the study were trapping and handlining. The decrease in total catch with increased effort, the discontinuity in the 1974-75 age structure, the increased individual fish size of the 1976 catch, and particularly the spawning failure in 1976 indicated the need of management action. Fishing mortality accounted for 60-75% of the population in 1974-75 and 1976. The fishery also has an indirect effect on the grouper aggregation since large predators aggregate to feed on the catch, and interfere with the spawning aggregation.

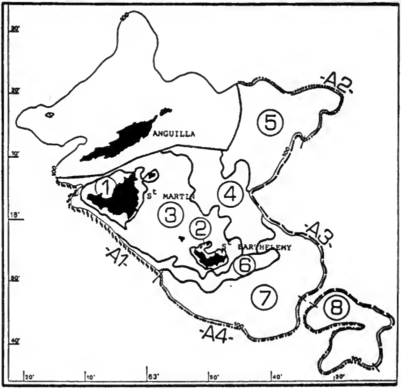

Fig. 4. Stratification of the Anguilla Bank for a trap and trammel net survey in 1986-1987 (Lorance and Huet, 1988)

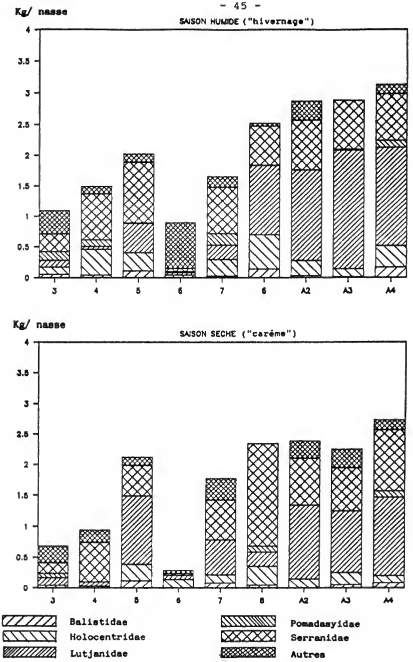

Fig. 5. The catch rates and catch composition by traps on the Anguilla Bank (Lorance and Huet, 1988)

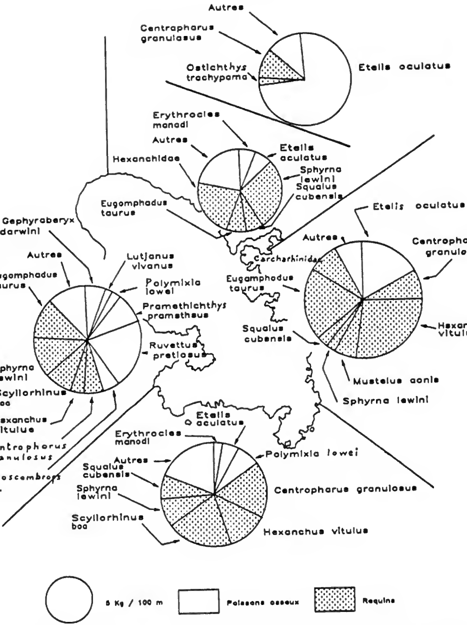

Fig. 6. The catch rates and catch composition of bony fishes and sharks in experimental fishing by trammel nets at 200-300 m in five strata off Martinique (Guillou, 1989)

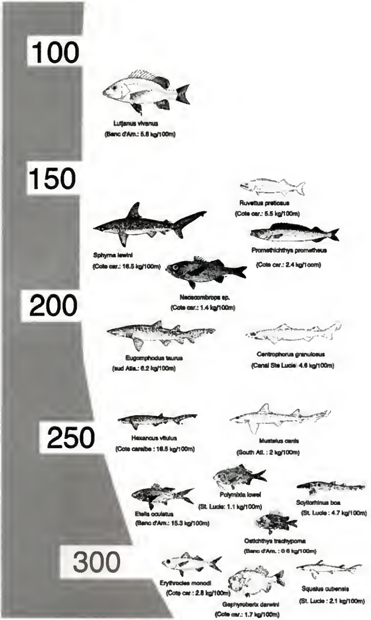

Fig. 7. The bathymetric distribution, maximum average catch rate, and stratum (see Fig. 6) in which this was obtained, for the 16 species of commercial interest in trammel net catches at 100-300 m off Martinique (Guillou, 1989)

The red hind, *Epinephelus guttatus* is one of the most important species of reef fishes. The formation of large spawning aggregations makes this species particularly susceptible to overfishing. Beets and Friedlander (in press) report a significant decline in mean size of this species in the catch in St. Thomas, US Virgin Islands between 1984 and 1988 (335-297 mm). Yield-per-recruit analysis suggests that this species is being exploited at levels in excess of $F_{0.1}$ in St. Thomas waters (Sadovy and Figuerola, in press).

Potential yield

Application of yield per recruit assessment models to the multispecies trap and line fisheries for reef fishes is problematic, since the species usually differ in their biological characteristics and therefore their response to exploitation. The level of fishing or gear size which may be optimal for one may severely overexploit another.

There have been some studies of yield-per-recruit of the dominant species. Sadovy and Figuerola (in press) estimate F and $F_{0.1}$ values of 0.17 and 0.14 respectively for red hind in St. Thomas, US Virgin Islands. Gobert (in press b) examined the effects of various input values for yield-per-recruit of coney with reference to CPUE and size structure in Martinique, and concluded that no increase in yield-per-recruit could be expected. For *Haemulon plumieri* in Martinique, Chevaillier (1990) concluded on the basis of yield-per-recruit analysis that there was growth overfishing, and that the illegal 25 mm mesh traps should be eliminated.

Owing to the difficulties of applying analytical models to multispecies reef-fish fisheries, holistic approaches to estimating yield of reef fishes has frequently been raised as a high priority research item in the Caribbean. Estimates of yield per unit area of tropical shelf from other areas are variable. In general they range from about 0.5-5.0 mt/km$_2$/yr (Marten and Polovina, 1982; Caddy and Sharp, 1986; Ardill, 1983). This variability may be due to differences in productivity in similar habitats, differences in habitat composition, differences in extent of exploitation, and/or differences in species included in the estimate. Application of the above range of estimates to island shelves and shallow banks in the Lesser Antilles results in estimates of total yield of 11,000-110,000 mt/yr (Mahon, 1990c) (Table 2).

In Martinique, estimates of yield of demersal species in 1987 ranged from 0.24-8.45 mt/km^2/yr in various areas, with an average of 1.14 mt/km^2/yr (Gobert, 1991 MS). However, these resources are considered to be heavily exploited. Other estimates of yield per unit area for Lesser Antilles countries appear in Table 2.

The only estimate of potential yield per unit length of slope in the Caribbean (Pedro Banks) was based on observed catches at unknown exploitation rates, and might not be applicable to the eastern Caribbean. A rough estimate of yield for the Lesser Antilles was obtained by applying the results from an assessment program in the Marianas Archipelago to the perimeter distances of the islands shelves and banks in the Lesser Antilles. The resulting minimum and maximum estimates are about 450 and 2,000 mt/yr for the entire Lesser Antilles, excluding the US Virgin Islands (Mahon, 1990c) (Table 2).

3.3.5 Future directions

It is generally accepted that reef fish resources of the island platforms are extremely overexploited in most Lesser Antillean countries. Because of the resulting low yields from these fisheries, the potential importance of reef-fish fisheries as a source of local protein and part-time employment is frequently underestimated and fishery development tends to focus on expansion into pelagic resources. Rehabilitated and properly managed reef fish resources can provide a continuous relatively stable yield which is easily accessible with a minimum investment in fishing gear. Therefore, a primary objective should be the rebuilding of reef fish populations. Monitoring of trends in abundance and species composition will be essential part of any attempt to rehabilitate reef fish resources.

The extent to which reef fish populations are limited by recruitment is the subject of considerable debate among scientists. If recruitment is a limiting factor, recruitment overfishing may be a significant factor in the depletion of reef fish stocks. This may be most significant in instances where spawning aggregations are heavily exploited. Alternatively, if the availability of recruits usually exceeds the available space for newly settled juveniles, then growth overfishing will be of primary concern. The relative importance of recruitment and space is likely to vary from place to place, even within the Lesser Antilles, depending on the location of the island relative to sources of recruitment and prevailing currents.

Although yield-per-recruit optimization for multispecies reef fish fisheries will be technically complex, and will require considerable amounts of data, yield-per-recruit analyses on certain key species may still be appropriate as indicators of their status. However, availability of expertise and funding may dictate that primary consideration be given to trends in indicators such as species composition, fish size, and maturity.

In the absence of information on stock-recruitment relationships (which is unlikely to become available in the foreseeable future) a simple first step is to minimise the harvesting of immature (juvenile) fishes. Size at maturity would be the basic information required. This basic information is not available for most reef fish species. Marine reserves and closed areas may have an important, but as yet unevaluated role to play in providing sources of recruitment, and also protecting known spawning aggregations. Monitoring of populations of demersal fishes in marine reserves can also contribute to knowledge of the rates of rebuilding and production of stocks.

For the fish resources of deep slopes and banks, which are based on fewer species than those on the island shelves, standard stock assessment approaches may be more feasible. Yield-per-recruit analyses, coupled with estimates of fishing mortality, may be appropriate means of estimating sustainable levels of fishing effort.

For all species which aggregate for spawning, the locations and timing of aggregation should be documented, and these areas protected at spawning times.

The lack of estimates of potential yield for island shelves and slopes in the Lesser Antilles continues to make it difficult to recommend appropriate interim levels of fishing effort, while more detailed assessments are being carried out. The only feasible approach to a short-term general production estimate of potential yield would be to use each island as a separate catch and effort data point (Caddy and Garcia, 1983), as was done for the parishes of Jamaica (Munro, 1977). For this method to work, there would have to be variability among the islands in the amount of effort (fishing mortality) being exerted on the stock. This could be measured as effort per unit area, or directly as fishing mortality. There are a number of complicating factors which would make the practical application of this approach difficult (see Mahon, 1990c).

Throughout the eastern Caribbean, there is evidence that urban, industrial and tourist development is having significant negative impacts on coastal marine habitats. In certain instances, these impacts are becoming evident on offshore reefs as well (Rogers, 1985; Hunte, 1988). Degradation and destruction of coastal marine habitats in the Lesser Antilles is potentially problematic for shallow-shelf reef-fish resources in two ways. First, many of the most threatened habitats, close to shore, such as mangroves and seagrass beds, are important nursery areas for juveniles of harvested demersal fishes. Reduction in the extent of these habitats may result in reduced recruitment to demersal fish populations. Secondly, loss of live coral, and other changes in reef structure leading to loss of cover and diversity can be expected to reduce the abundance of exploited species (Rogers, 1985; Bouchon, et al., 1987).

3.4 Large Pelagics

3.4.1 Overview of the fishery

Large offshore pelagic fish resources are generally considered to hold the greatest potential for development and most Lesser Antilles countries are attempting to increase the effort in these fisheries. The catch consists of several species with a wide variety of life histories: tunas, billfishes, dolphinfish, wahoo, kingfish, sharks. Most of these species show marked seasonal availability in the subregion. They are usually exploited all together on the same fishing trips, frequently along with flyingfish, by boats ranging from canoes with outboard engines (St. Lucia, Dominica) to larger inboard powered launches with ice containers (Barbados). Trolling has been the traditional method of fishing. More recently, small-scale longlines have been introduced; with considerable success in Grenada. Distant water fishing nations, and other countries in the wider Caribbean are known to fish in the EEZs of the Lesser

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Antilles, historically for yellowfin and skipjack tuna, and recently also for swordfish. Without substantial investment in large commercial scale vessels, the catch of large pelagics by Lesser Antilles countries will probably remain a relatively minor proportion of the total landings from western Atlantic stocks.

Large pelagics are more important in the Windward Islands and Barbados than in the Leeward Islands. The composition of the catch varies from island to island, but dolphinfish, yellowfin tuna and wahoo are the most important large pelagics (Table 15). Although large pelagics comprise a single fishery in most places, they vary widely in distribution, migratory patterns and in their potential for development. Following the conclusions reached in the Expert Consultation on Shared Fishery Resources of the Lesser Antilles (Mahon, 1987), these species are considered in two groups:

- species for which stocks are probably contained within the Lesser Antilles region (species generally considered to be more coastal than species in the second category);
- species for which stocks extend throughout the Atlantic, or at least the western Atlantic (species which tend to be oceanic and highly migratory).

Most of the species in both categories are assessed by ICCAT, but the status of the stocks is poorly known, especially in the Western Atlantic where the data base is weak. Unless otherwise referenced, the information presented below is summarised from papers in the Report and Proceedings of the Expert Consultation on Shared Fishery Resources of the Lesser Antilles (Mahon, 1987; Hunte, 1987b; Mahon and Mahon, 1987), the background paper for the Caribbean Fisheries Management Council Management Plan (Centaur Assoc., 1983) Workshop.

Evidence for the assumption that stocks of some species are localised in the Lesser Antilles, and probably migrate within the subregion, is largely circumstantial. Species which are generally coastal are considered most likely to display the above pattern. However, there is little reason to believe that the Grenada passage in the south, or the Anegada or Mona Passages in the north, are barriers to migration/dispersal of these species.

The most important species for which stocks may be contained within the EEZs of the countries of the Lesser Antilles subregion are: dolphinfish (Coryphaena hippurus), blackfin tuna (Thunnus atlanticus), little tunny (Euthynnus alletteratus), Scomberomorus species (king and cero mackerel). Bonito (Sarda saarda), and carangids such as amberjacks (Seriola spp.), rainbow runner (Elegatis bipinnulatus), and blue runner (Caranx crysos), are less important species in this category.

Dolphinfish is probably the most important of the above species, as is highly seasonal. They are taken primarily by trolling, and more recently by longlining. Dolphinfish are not targeted by any of the foreign fleets, but are bycatch in longlining for tuna. 'Kingfish' are also a significant part of the catch. However, a major problem is that in many islands,

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Table 15. The percentage composition of the catch of offshore pelagic fishes in Barbados (in 10 year periods), Grenada (1981-1989), St. Lucia (1984-1989), and St. Vincent (1979-1989) (from Mahon et al., 1990)

BARBADOS

Species/Group	Speightstown			Oistins		
	1960s	1970s	1980s	1960s	1970s	1980s
Flyingfish	81.5	80.0	83.5	55.4	40.3	53.8
Dolphinfish	10.3	13.3	13.0	29.3	48.3	34.4
Kingfish	1.0	1.1	1.0	6.8	6.4	6.6
Sharks	2.2	1.8	0.8	3.1	1.0	1.1
Tuna	3.6	1.3	0.5	3.2	2.2	1.8
Billfishes	1.4	2.5	1.2	2.2	1.8	2.3

GRENADA

Species/group	Gouyave	Melville St.	Grenville
Flyingfish	6.8	21.4	0.1
Dolphinfish	8.0	7.2	17.9
Kingfish	2.5	2.3	17.2
Yellowfin tuna	47.3	41.6	1.5
Small tunas	-	-	55.0
Skipjack tuna	<0.1	0.6	4.3
Atlantic sailfish	28.2	13.9	0.9
Marlin	3.9	3.6	<0.1
Sharks	2.5	4.6	0.1
Rainbow runner	-	-	<0.1
Scomberomorus spp.	-	0.3	-
Barracuda	0.6	2.1	2.8

ST. LUCIA

Species group	Dennery	Micoud	Vieux Fort
Dolphinfish	34.2	37.8	36.0
Kingfish	21.8	21.8	20.0
Yellowfin tuna	20.6	17.3	20.8
Skipjack tuna	20.6	14.8	17.9
Blackfin tuna	0.2	3.1	2.0
Billfish	0.2	0.1	1.2
Flyingfish	2.3	5.2	2.0

ST. VINCENT

Species group	Kingstown
Dolphinfish	38.2
'Small tuna'	27.3
Blackfin tuna	23.0
Wahoo	5.9
Cavalli	2.9
Rainbow runner	1.1
Sharks	0.8
Yellowfin tuna	0.5
Barracuda	0.2
Billfish	0.1

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both Scomberomorus species and wahoo are recorded as 'kingfish'. Therefore, it is impossible to evaluate the relative contribution of these species or to examine their seasonality. In a few places, studies indicate that most of the 'kingfish' catch is wahoo. There is no mention of S. regalis, cero mackerel, as a component of the catch in any islands except the US Virgin Islands and Martinique. It was a regular but not abundant component of the catch in exploratory trolling in the late 1960s and early 1970s. This species should be common in the eastern Caribbean, and as mentioned above is almost certainly recorded as kingfish.

Blackfin tuna are sufficiently abundant in the eastern Caribbean to support artisanal fisheries. Blackfin have traditionally been exploited by most of the Windward Islands. However, they are usually recorded as small tunas, or in Barbados as bonito. Little tunny are also harvested regularly by multispecies artisanal fisheries using seines and trolling. Islands which have been reported to catch little tunny (or spotted bonito, as they are often called) are: the Virgin Islands, Martinique, Dominica, St. Lucia, and Grenada. However, Hunte (1987b) does not refer to this species, which suggests that it may be recorded as bonito or some other tuna.

The most important species for which stocks are known to extend outside the EEZs of the countries of the Lesser Antilles subregion are the tunas and billfishes. The most common tunas in this category are: yellowfin tuna (Thunnus albacares), skipjack tuna (Katsuwonus pelamis) and to a lesser, poorly documented extent, bigeye tuna (T. obesus) Albacore (T. alalunga) are caught mainly in the northeastern islands.

The billfishes most often mentioned in accounts of fisheries in the Lesser Antilles are blue marlin (Makaira nigricans) and Atlantic sailfish (Istiophorus albicans). These two species support valuable recreational fisheries and contribute to the catch of multispecies artisanal fisheries for pelagics. White marlin (Tetrapterus albidus) and longbill spearfish (T. pfluegeri) also occur in the eastern Caribbean but contribute much less to the catch. Swordfish (Xiphias gladiator) is a particularly important species in this category having recently been the focus of a shift in targeted effort from the eastern USA to the Caribbean region. The artisanal fisheries of the Lesser Antilles have caught sailfish for decades but separate records are few. ICCAT shows records for the Netherlands Antilles and Grenada for 1974-1984, with annual catches of about 50 and 25 metric tons respectively. In Barbados, the billfish catch is comprised of equal numeric proportions of sailfish, blue marlin, and white marlin (Oxenford, 1990).

Yellowfin tuna are an important component of the small-scale multispecies fisheries. However, most of the catch from the western Atlantic stock is taken by longliners from Venezuela, Cuba, Japan, Korea, and Taiwan, and recently by purse seiners from Venezuela.

The numbers of bigeye tuna caught in the eastern Caribbean are difficult to determine since catches are low and records are scarce. Bigeye are occasionally taken by artisanal fisheries of the Caribbean islands and by Japanese, Brazilian and Venezuelan commercial fisheries. There are no data on the numbers of bigeye caught in the eastern Caribbean by Venezuelan, Japanese or Brazilian vessels.

The importance of skipjack tuna in the small-scale fisheries is difficult to evaluate as they are often recorded as small tuna, or bonito. Skipjack catches of Dominica and St. Lucia, using handlines, trolling and seine-netting, remained around 80 and 100 mt/yr during the period 1976-1982. Barbados reported catches of 78 and 72 mt for 1981 and 1982 respectively. As with yellowfin tuna, most of the catch in the subregion is by large-scale commercial vessels from other countries.

There are few records of albacore catches in the eastern Caribbean. However, albacore are most common around the Leeward Islands during April-August. The Japanese longline fishery (1956-68) caught most albacore in this region from April-June.

In the Lesser Antilles subregion, swordfish are rarely reported as recreational or artisanal catch, probably because most fisheries operate during the day when swordfish are unavailable at the surface. However, during the 1980s, there was an increasing presence of foreign swordfishing vessels in the Lesser Antilles which focused attention on the potential of this resource. In the winter of 1983-84, in response to declining catch rates elsewhere, US swordfish vessels began to explore the waters around the Caribbean islands. Berkeley (1987) reports that in the 1984-85 season, there were about 2-25 boats fishing in the vicinity of Puerto Rico and the US/British Virgin Islands. By the 1985-86 season as many as 43 vessels from the eastern US were operating out of San Juan. Since then, US swordfish vessels have extended their operations southward through the eastern Caribbean islands to the north coast of South America. Several of these vessels have been fishing under joint venture arrangements with various eastern Caribbean islands. Although the actual number of boats fishing in the area is unknown the rate of the expansion of the US swordfish fishery into the Caribbean is indicated by the increase in the percent of total landings coming from this area shown in the following table:

Year	1983	1984	1985	1986	1987	1988
Caribbean landings (mt)	0	25	396	1153	1014	681
Percent of US total	0	<1	9	24	21	12

The 1983-1986 data are from Hoey and Bertolino (1988), and the 1987 and 1988 data are from A. Bertolino, NOAA, NMFS, SEFC (in lit.).

The possible impact that swordfish longline vessels might have on non-target species, particularly those which are exploited by the small-scale fisheries of the eastern Caribbean islands, was explored using logbook data for 1192 longline sets in the Lesser Antilles area. These were used to determine the reported catch rates for the target and bycatch species in the eastern Caribbean, and to estimate the total catch of species other than swordfish taken by US longliners from the Caribbean region in 1986 (Table 16) (Mahon, 1990a).

The logbook records indicate that about 75% of the catch is swordfish, yellowfin tuna and bigeye tuna, while sharks, most of which are discarded, comprise about 20%. Of the above species, yellowfin tuna, and sharks are of significance to the small-scale fisheries in the region; swordfish are not exploited, and bigeye tuna are of minor significance. Species which are commonly taken by small-scale fishermen, such as dolphinfish, wahoo, blackfin tuna, sailfish and marlin, comprise a relatively small proportion of the catch by these vessels. These findings are consistent with records for six fishing trips by a longliner based in Grenada (Table 17). Some islands have become involved in swordfish fishing, and Grenada has boats actively engaged in swordfish fishing (Finlay, 1989).

Sport fishing is an important component of the tourist industry in many islands of the Lesser Antilles, particularly in the US Virgin Islands and British Virgin Islands (Walters, 1983; Brandon, 1987; Friedlander, 1990). However, other than in the US Virgin Islands there is little information on the landings by charter or private sportfishing boats.

3.4.2 Stock structure, migration and dispersal

Definition of stock structure will be very difficult for most large pelagics. Even for the commercially important tunas, the ICCAT Standing Committee on Research and Statistics has not reached many scientifically rigorous conclusions. These fishes are generally too valuable to tag in large numbers and require special handling for successful tagging and release. Seasonal distribution provides some clues to migration and distribution, but data from commercial fleets are frequently incomplete. The following information has been taken primarily from a review of stock structure and migration of pelagic fishes which are exploited in the Lesser Antilles (Mahon and Mahon, 1987).

The limited available data from the eastern Caribbean show marked seasonality for many species, but it is currently impossible to distinguish between directional migration and onshore-offshore movements (Figure 8). One feature is notable, most species are absent from the eastern Caribbean from July to September (Mahon et al., 1990) (Table 17).

For dolphinfish, seasonality and size-frequency data suggest that there is one stock in the eastern Caribbean region (Oxenford and Hunte, 1986; 1987a). Comparisons of various population parameters, and seasonality suggest that this stock may be separate from that off the eastern USA. However, the location of the division between the stocks is unclear, as are factors which might be responsible for their separation (Mahon and Mahon, 1987).

In the eastern USA and Gulf of Mexico Scomberomorus spp. show regular seasonal migrations along the coast and remain on the continental shelf. This suggests that Scomberomorus species

Table 16. Catch rates for pelagic species taken by US longliners in the eastern Caribbean in 1988. These data are for 1,192 sets using a total of 423,809 hooks. Estimated total catch of species other than swordfish from the Caribbean, by US longliners in 1986 is based on the ratios of numbers of each species to numbers of swordfish in column 1, and on a total catch of 24,331 swordfish from the Caribbean for 1986 (Hoey and Nelson (1988) from Mahon (1990a)

Species	Total number	Percent total #	Catch/ 100 hks	Percent discarded	Est. # caught '86
Swordfish	13,351	55.5	3.20	0	
Yellowfin tuna	2,225	9.3	0.50	2	4,055
Bigeye tuna	2,222	9.2	0.53	1	4,049
Bluefin tuna	14	0.1	<0.01	0	26
Albacore	81	0.3	0.02	14	148
Blackfin tuna	208	0.8	0.05	9	379
Other tuna	171	0.7	0.03	23	312
Dolphinfish	401	1.7	0.09	1	731
Wahoo	83	0.3	0.02	5	151
Scomberomorus	1	<0.1	<0.01	0	2
Spearfish	25	0.2	0.01	83	46
White marlin	116	0.5	0.03	60	211
Blue marlin	234	1.0	0.06	76	426
Sailfish	92	0.4	0.02	67	168
Sharks	4,843	20.1	1.06	84	8,826
Total	24,067		5.64		

Table 17. Composition of the catch by a longline vessel based in Grenada (data provided by Grenada Fisheries Division) (Mahon, 1990a)

Species	Catch (kg)	Percent
Swordfish	17,745	77.8
Yellowfin tuna	2,349	10.3
Bigeye tuna	1,961	8.6
Dolphinfish	69	0.3
Marlin	218	1.0
Sailfish	42	0.2
Shark	436	1.9
Total	22,820	

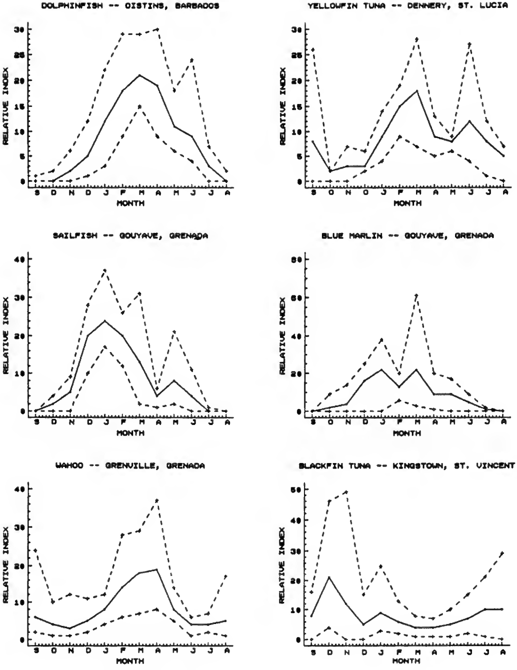

Fig. 8. Average seasonal patterns for some large pelagic species (modified from Mahon et al., 1990)

in the eastern Caribbean might migrate along the island chain. Indeed, these species are usually caught on or near island shelves. Channels between islands are unlikely to restrict movement of these species. Puerto Rican fishermen and biologists believe there is a westward migration along the edge of the shelf off Puerto Rico from November to April, and that king mackerel leave the Virgin Islands in October, arriving off the east coast of Puerto Rico in November and off the west coast several weeks later (Centaur Assoc., 1983). The lack of clear seasonality of kingfish in the eastern Caribbean may be due to recording of Scomberomorus spp. and wahoo together as kingfish.

Stock structure of blackfin tuna is unknown, although they are considered to be coastal in habit. ICCAT (1991) only mentions this species in the group 'small tuna', and stresses the need for special efforts to record and report the catches of these and other small tunas. Preliminary indications are that this species is present around the islands year-round (Mahon et al., 1990).

Fishermen and biologists suggest that little tunny migrate east-west along the outer edge of the island shelf (drop-off) from the Virgin Islands past Puerto Rico to the Dominican Republic, and back (Centaur Assoc., 1983). Trolling explorations in the Leeward Islands caught most little tunny during March-May. There are no studies of these fish in the eastern Caribbean.

ICCAT (1991) espouses a two stock hypothesis for Atlantic yellowfin tuna, with discrete east and west Atlantic stocks separated at 30°W. Most analysis and information available in the ICCAT literature is for the eastern stock. In the western Atlantic, an early analysis of Venezuelan fishing patterns showed that effort tended to shift from the Caribbean to the Atlantic during the fourth and first quarters. Migration of yellowfin tuna between the two fishing areas was postulated. Subsequent analysis has suggested that there may be separate Caribbean and West Atlantic Ocean stocks.

Movements of skipjack within, as well as into and out of, the Lesser Antilles Subregion are suggested by the seasonality in catches, but have not been studied. There is no specific information on stock structure of skipjack tuna in the Lesser Antilles. ICCAT (1991) considers them part of a single western Atlantic skipjack stock, currently thought to be separate from another stock in the eastern Atlantic.

ICCAT analyses are based on the hypothesis of a single Atlantic wide stock of bigeye tuna. Most authorities agree that there are two stocks (or sub-populations) of albacore in the Atlantic; a northern stock separated from a southern stock at 5°N. However, there is uncertainty as to which stock the fish caught in the Lesser Antilles belong to. They are probably most closely associated with the north Atlantic stock.

Tagging indicates two or three stocks of swordfish in the Atlantic Ocean: (1) the northeastern Atlantic stock, with concentrations just off the Mediterranean Sea from September to December; (2) the northwestern Atlantic stock from Newfoundland to the Caribbean Sea; and (3) the southern Atlantic stock, with concentrations off Uruguay and Argentina from April to October. Until recently, ICCAT has considered that swordfish caught in the eastern Caribbean are probably part of a northwest Atlantic stock, but are now leaning towards an hypothesis of one large North Atlantic stock.

Tagging studies show that western Atlantic sailfish migrate between summer areas in the northern Gulf of Mexico and around Jacksonville-Cape Hatteras, and winter areas near southeastern Florida, through Cuba and the Virgin Islands, with recaptures as far south as Grenada and Guyana. The seasonality of fisheries also indicates that Atlantic sailfish are most numerous in the Gulf of Mexico and western Caribbean during the summer and most numerous in the eastern Caribbean during the winter, with peaks in abundance during July and January, respectively. ICCAT (1991) analyses are based on a single western Atlantic stock.

There appear to be two major concentrations of Atlantic blue marlin; one in the southwest Atlantic off the easternmost part of South America, and one in the northwest Atlantic in the Gulf of Mexico and Caribbean. Tagging reveals that white marlin migrate between feeding, wintering and spawning areas along routes that may extend from Brazil to Canada. The migratory routes of these fish are unknown but they may include both coastal and oceanic waters, as far east as longitude 40°W, where tagged fish have been recovered. The white marlin that aggregate off Venezuela have been found to move either south or north.

3.4.3 Biology and ecology

Dolphinfish is the only large pelagic fish which has received any significant attention in the Lesser Antilles subregion. A study by Oxenford (1985) examined growth, feeding, reproduction and migration, as well as trends in abundance and in the fishery for this species. Dolphinfish were aged using daily growth rings in otoliths (Oxenford and Hunte, 1984). Growth is rapid and the lifespan is short. The maximum observed age and length were about 1 year and 110 cm respectively. The estimated growth parameters are as follows (Oxenford, 1985):

Group	L_∞ (mm SL)	K	t_o
All fish including juveniles	1208	3.49	0.055
Males	1260	5.24	0.089
Females	1221	3.43	0.063

Instantaneous natural mortality was estimated at 2.55 for all fish (3.30 for males and 2.52 for females), whereas fishing mortality was estimated as 1.37-3.29 by various methods (Oxenford, 1985).

Dolphinfish have an extended spawning season and are probably multiple spawners. The timing and extent of the spawning season vary with the locality. Off Barbados, spawning appears to extend throughout most of the year. The size at maturity (SL) off Barbados was 610 mm for females and 735 mm for males. Fecundity ranged between 101,100-6,016,003 total eggs, and 16,628-1,243,770 mature eggs (Oxenford, 1985).

In St. Lucia, Murray and Sarvay (1987) and Murray and Nichols (1990) have analysed length frequency data for wahoo to obtain growth parameters. They concluded that there were insufficient data on young fish to estimate L_{∞}, but were able to estimate a probable K value of about 0.32/yr.

3.4.4 Stock assessment

Exploratory fishing

The UNDP/FAO Fishery Development Project carried out exploratory fishing with longlines which consisted of a 210-fathom main line with six branch lines placed at 30-fathom intervals (Kawaguchi, 1974a). In the Northeast Region (Anegada Passage) one set of 354 hooks in January 1966 caught no fish. In August 1967, a set of 540 hooks west of Dominica caught no fish in comparison with seven tunas caught east of Dominica. In the Anegada Passage, three sets utilizing 1,680 hooks close to Sombrero Island in August 1967, caught 16 tuna -- 5 yellowfin tuna, 9 albacore, and 2 large skipjack tuna. During December 1966, one 180-hook set just east of St. Vincent took no fish. In January another set of 420 hooks south to 12N° east of Grenada caught six tuna -- 4 yellowfin tuna and 2 bigeye tuna, together with 7 white marlin. In February, 10 sets utilizing 4,002 hooks between the southern Lesser Antilles arc and 55°W took few fish. In the Leeward Islands Region, 6 sets were made in July and 5 sets in August 1967. The former ranged in distance from 17 miles northeast of Barbuda Island to 180 miles east of Guadeloupe. The latter ranged from 30 miles east of Dominica Island to 210 miles east of Antigua.

The UNDP/FAO Project also conducted exploratory fishing between 1967 and 1970 for tuna using pole and line. The operations included the Antillean Arc (Wagner, 1974) with the area surrounding the Windward Islands receiving most coverage. Separate catch rates are not given for the Lesser Antilles, but overall tuna catches were as high as 73 pounds per hour, and averaged 24 pounds per hour near the Windward Islands in 1970. They were mostly skipjack tuna, but blackfin tuna and yellowfin tuna were also taken. Dolphinfish, rainbow runner, frigate mackerel and little tunny were also observed.

Exploratory and experimental troll fishing or "towing" was also carried out by the UNDP/FAO Project vessels: Alcyon, Calamar, and Fregata (Wagner and Wolf, 1974). Table 18 shows the species composition of exploratory trolling cruises by area and month in the northern and southern Lesser Antilles.

Sacchi et al., (1981) describe the results of trolling and live bait fishing surveys in the Caribbean Sea from 1976 to 1978. The largest numbers of shoals were encountered at reef edges of 100 m, mainly at the openings of canals and off the Venezuelan

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Table 18. Seasonality of the major species and species groups of pelagic fishes in the eastern Caribbean (from Mahon et al., 1990)

Species and species groups	Seasonality based on:		Location
	Average pattern	Individual years	
Dolphinfish	Unimodal Feb-April	Usually unimodal, occasional shoulder	Oistins
	Unimodal Feb-April	Usually one large peak with small second peak or shoulder	Speightstown
	Bimodal Feb-Mar & May	Bimodal in most years	Gouyave
	Trimodal Nov, Feb-Mar & May-June	Bimodal in most years, trimodal in one	Melville St.
	Unimodal Feb-April	One large peak with occasional small second peak or shoulder	Kingstown
	Unimodal Feb-April	Bimodal in 1/5 seasons	Dennery
Kingfish (Wahoo)	Slightly bimodal Jan-June	Frequently bi/tri-modal	Oistins
	Virtually no seasonal pattern	Spikey with several modes	Speightstown
	Bimodal Dec-Feb & Apr-June	Spikey with several modes	Gouyave
	Jan.-May	Unimodal with a small spike in some years	Grenville
	Bimodal Feb & May	Bi/trimodal in most years	Kingstown
	Unimodal Feb-June	uni/bi/trimodal	
Yellowfin tuna	Bimodal Dec & June	Usually bi- occasionally trimodal	Oistins
	Bimodal Dec & May	Usually bi- occasionally trimodal	Speightstown
	Bi/trimodal Nov-Jan & May-June	Bi/trimodal in most years	Gouyave
	Bi/trimodal Nov, Mar, May	Bi/trimodal in most years	Melville St.
	Uni/bimodal very flat	Scattered very sharp peaks	Kingstown
	Bimodal March-June	Uni/bi/trimodal	Dennery
Blackfin tuna	Bimodal Oct (main) & Jan	Spikey but appears trimodal	Kingstown
Skipjack tuna	Unimodal March	Usually one large peak	Grenville
Sailfish	Bimodal Dec-Feb & May	Bimodal in most years, first peak large, second smaller	Gouyave
	Bimodal Dec-Feb & May	Same as above	Melville St.
Billfish	Bimodal (barely) Dec & April	Spikey	Oistins
	Bi/trimodal Nov-Dec & April	Spikey	Speightstown
Flyingfish	Unimodal May	Frequently bimodal	Oistins
	Unimodal May	Frequently bimodal	Speightstown
	Bimodal Jan & May-June	Typically one large mode in Jan and one small one May-June	Melville St.
	Bimodal Jan & June	Typically bi- occasionally trimodal	Dennery
Cavalli	Slightly bimodal Oct-Nov & Jan	Often bimodal sometimes trimodal	Kingstown

coast, the site of an important upwelling. With 95% of Thunnidae (Thunnus albacores, Thunnus atlanticus, Katsuwonus pelamis), catches made during these surveys vary between 50 and 250 kg/day at sea, depending on the geographic zone or the type of shoals encountered. These range from small shoals of "bonito" (small Thunnidae) of 1 to 2 tons, to "wood" (fishes swimming under flotsam) or "matt" of tuna, which can amount to 100 t (off Venezuela).

FADs

Two types of FADs, a commercial parasol type and a locally fabricated fishing net/automobile tyre type were deployed at three sites off the leeward coast of St. Kitts. Strike rates in the vicinity of the FADs appeared to be higher than adjacent areas, especially for wahoo and barracuda (Wilkins and Goodwin, 1989). In the US Virgin Islands a FAD made of locally available materials, easily deployed from a small boat, was found to increase the number of fish caught trolling during the summer months (Clavijo, et al., 1989). In Grenada, a FAD was deployed on the east coast, east of Grenville, in 1989, in about 800 m depth (Overa, 1989), but no results are available yet for fishing in the vicinity of this FAD.

ICCAT assessment activities

Most of the quantitative assessment of large pelagic stocks of importance in the Lesser Antilles subregion is carried out under the auspices of ICCAT. Until recently, the focus with regard to tunas has been primarily on the eastern Atlantic stocks. However, in 1990, ICCAT formed the Working Group on West Atlantic Tropical Tunas, which met for the first time in April, 1991 (B. Brown, NMFS, SEFC, in lit.). The results of ICCATs assessments in 1990 are summarised below (ICCAT, 1991).

Yellowfin tuna: In 1990, the first production model analysis of western Atlantic yellowfin tuna was carried out for ICCAT. It was based on Venezuelan catch and effort data. The model suggested an MSY at about 31,000 mt, with the stock being near full exploitation. These results and future analyses are of considerable importance to lesser Antilles countries, as the fishing areas of the longline, purse seine and baitboat fleets was shown to extend through the southern Lesser Antilles. The focus of the first meeting of the Working Group on West Atlantic Tropical Tunas was on yellowfin tuna. The working group identified the additional data on biological parameters, and catches which would be required before an analytical assessment could be undertaken.

Bigeye tuna: MSY for the entire Atlantic stock has been estimated at about 70,000 mt. At about 60,000 mt current landings are below MSY. However, the potential for increased catches of bigeye tuna in the western Atlantic is unknown.

Albacore: There are no specific data on abundance or catch trends in the eastern Caribbean. Those for the entire North Atlantic show a decrease between 1967-71 after which the abundance of these fish has stabilized. Despite apparent declining recruitment, ICCAT considers the stock to be in good condition.

Skipjack tuna: In 1990, the first production model analysis of western Atlantic skipjack tuna was carried out by ICCAT. The estimated MSY of about 33,000 mt/yr was presented with several caveats, but indicates that at current levels of landings (29,000 mt/yr), the stock may be at, or near, full exploitation.

Swordfish: Owing to the value of the fishery and its recent expansion into the Caribbean, assessment of the status of the North Atlantic swordfish stock has been the subject of considerable recent activity. The most notable trend in the fishery has been the decline in mean weight of fish in the catch. This trend has been evident in all areas. Yield-per-recruit analyses indicate that current levels of fishing mortality exceed F_{max} over a wide range of input assumptions.

Sailfish: ICCAT considers west Atlantic sailfish to be only moderately exploited. This is based on a 1983 yield/recruit analysis which suggested that fishing mortality was about 20% below $F_{0.1}$. Confirmation of this conclusion by virtual population or production analysis is not possible owing to deficiencies in the data.

Blue marlin: Catches of blue marlin during the early 1970s are considered to have been near the maximum sustainable yield. This view is supported by the gradual decrease in Japanese longline CPUE during the 1970s, and the fact that it remains well below that of the late 1960s. Although the status of the stock is uncertain, and recent effort may have been below that required for MSY, continued low catch rates, and the recent increase in longline fishing effort in the Caribbean where blue marlin are known to occur, give cause for caution.

White marlin: White marlin catches show a slow, steady decline from 1974 to the present. Although, ICCAT remains uncertain of the status of this resource, there is probably little potential for increased yield.

Small tunas: This category includes several species which are of considerable importance in the Lesser Antilles subregion: Atlantic bonito, Atlantic black skipjack (blackfin tuna), Spanish and king mackerels, and wahoo. ICCAT (1991) idicates that there is not enough information on these species to allow an evaluation of the status of the stocks.

Assessment analyses carried out in Lesser Antilles countries

Some time-series of catch and CPUE are available for large pelagics in various islands of the Lesser Antilles (Hunte, 1987b). Mahon (1990a) has examined trends in effort in commercial and artisanal fisheries for large pelagics in the western Atlantic, with particular reference to the possible effects on fisheries in the Lesser Antilles. The most significant trend was in the landings by Barbados, due to fleet expansion. Catches of yellowfin and skipjack tunas by Venezuelan commercial vessels also fluctuated considerably during the 1980s.

Time-series of catch and effort for pelagics are longest and most complete in Barbados. However, data from Grenada, St. Vincent, St. Lucia, and the US Virgin Islands have been used in various analyses. Olsen and Wood (1983) used catches from a charterboat logbook to describe seasonal patterns and interannual variability. Oxenford and Hunte (1987b) examined trends in dolphinfish CPUE in Barbados. Mahon et al., (1990) examined seasonality and interannual variability in catches and CPUE for all important large pelagics using data from Grenada, Barbados, St. Vincent and St. Lucia. This analysis shows substantial interannual variability in abundance/availability but does not reveal any trends.

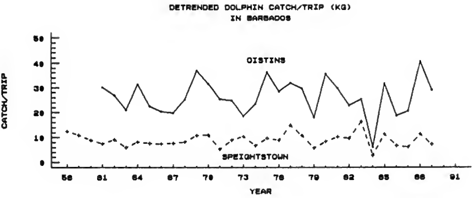
Dolphinfish do not come under the auspices of ICCAT. Assessment of dolphinfish stocks in the Lesser Antilles subregion has consisted of analysis of trends in abundance indices (see above), including possible environmental effects on abundance, and stock-recruitment relationships (Oxenford and Hunte, 1987b; Mahon, 1990a; 1990b). The catch per unit effort time-series from Barbados was detrended, due to trends in fishing power of launches (Oxenford, 1985), and used to examine possible stock-recruitment relationships (Mahon, 1990b) (Figure 9). The lack of an apparent relationship indicates that the variability in dolphinfish abundance indicated by the time-series is not associated with spawning stock size, and that the fishery has not yet impacted the stock to the point where recruitment has been affected.

Andrews (1990) examined sailfish and blue marlin landings from Grenada for the period 1978-1988 and showed that catches of the former had recently increased threefold. In contrast, in Barbados, there had been a slight decrease in billfish landings over the time period for which data were available 1958-1988 (Oxenford, 1990). In the US Virgin Islands, there has been a trend of increasing CPUE for blue marlin between 1983 and 1989 (Friedlander, 1990).

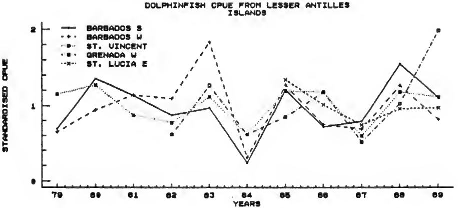
Potential yield

Without better information on stock structure, and catches, only rough estimates of potential yield are possible, based on observed yields from intensely fished ocean and near island habitats in other tropical regions. Marcille and Caddy (1987) have made such estimates for the Lesser Antilles by extrapolating catches in those islands with pelagic fisheries to those with none. On the basis of comparison with catch-per-unit shoreline in other parts of the Atlantic, they adjust the total upwards slightly; with due consideration for low productivity due to nutrient limitation in the Lesser Antilles. They estimate a production potential of 6,000-7,000 mt of small tuna-like species, not including dolphinfish. Comparing this to the 1985 reported catches of 2,000-4,000 mt, they conclude that landings could be increased by 50-80% above 1985 levels in islands with pelagic fisheries, and expanded to similar levels in those islands which do not currently harvest pelagics.

Marcille and Caddy (1987) have also estimated yields for oceanwide species such as yellowfin and skipjack tuna in two



DETRENDED DOLPHIN CATCH/TRIP (KG) IN BARBADOS



DOLPHINFISH CPUE FROM LESSER ANTILLES ISLANDS

Fig. 9. Long-term variability in CPUE for dolphinfish, and correspondence among CPUE indices for dolphinfish in various southern Lesser Antilles islands (modified from Mahon et al., 1990)

relevant areas: the southern Lesser Antilles, together with Trinidad and eastern Venezuela; and the Northern Lesser Antilles including eastern Puerto Rico. The estimates are based on observed yields (per one degree square of ocean) of such species from other areas of the tropical Atlantic. A potential yield value of 660 mt/yr/degree square has been postulated for a rich intensely exploited oceanic zone, with a minimum of 100 mt/yr/degree square. The larger value was applied to the southern Lesser Antilles/Trinidad/Venezuela, whereas the lower value was considered appropriate for the northern Lesser Antilles/Puerto Rico zone. In each zone, squares with coastal influences were assumed to have a potential yield of 1,200 mt/yr, a value approximating the coastal zone of Senegal.

The potential yield estimates for the northern and southern zones were about 14,000 mt/yr and 20,000 mt/yr respectively. These estimates could be redone to apply to the EEZs of the Lesser Antilles, and together with estimates of fishing capacity, would give a first approximation of a target fleet size for development purposes. There are several reasons why these estimates may be inappropriate. For example, productivity off west Africa is enhanced by upwelling, and there is no major area of upwelling in this region. This may be partly compensated by the nutrient inputs from the big South American rivers, but the extent to which this occurs, and how it might influence the Lesser Antilles, is unknown. It appears unlikely that coastal influence in the northern Lesser Antillean islands, with minimal runoff, can be comparable to those off West Africa. Thus, 1,200 mt/yr/degree square may be too high.

Marcille and Caddy's (1987) warnings about these estimates should be taken very seriously. They note that these yields can only be achieved at very high fishing effort, when catch per unit effort is relatively low. They advise that the target yields be set at 75% of their estimates, and that catch rates be monitored very closely as fishing effort increases.

3.4.5 Future directions

Given the impending expansion of fisheries on these species, especially in the Leeward Islands, and the virtual absence of data on their potential yields, there should be a considerable emphasis on monitoring catch and catch per unit effort. With accurate seasonal catch and effort data for 5-10 years and accompanying information on sizes of fish caught, the region would acquire a picture of migration, distribution and the response of the resource to increased fishing pressure.

Estimates of the type carried out by Marcille and Caddy (1987) should be refined, to establish the likely range of potential yield which could be expected from the EEZs of Lesser Antilles countries. Such estimates would involve substantial compilation of data from similar habitats in other parts of the world.

The large number of unanswered questions regarding migration patterns and stock structure of large pelagic species make it inappropriate for Lesser Antilles countries to consider any stock assessment based on estimates of stock size. Where data are available, these types of analyses are currently carried out under the auspices of ICCAT for several species. At this stage, the most productive use of regional time and expertise for wide ranging large pelagic species, would be to become involved in ICCAT activities, particulary those of the new Working Group on Western Atlantic Tropical Tunas. There should also be a focus on the establishment of data collection systems in the region. The data from these can be used to monitor trends in abundance and to define migration patterns and stock boundaries, and to permit meaningful participation in the assessment activities of ICCAT.

3.5 Flyingfish

3.5.1 Overview of the fishery

Flyingfish (Hirundichthys affinis) are the most important component of the fisheries for pelagic species in the south-eastern Caribbean, from Dominica to Tobago, with the exception of St. Vincent (Mahon et al., 1986). Total annual catch by all islands was estimated to be around 4,000-5,000 t with a landed value of about US$ 5.5 million. Barbados, the major participant in this fishery, has recently expanded its fleet, about doubling its catch between 1978 and 1989 (Mahon, 1990a). Other islands are developing their fisheries for pelagics in general, and for flyingfish in particular.

The fourwing flyingfish (Hirundichthys affinis) is believed to contribute more than 95% of the flyingfish catch in the Lesser Antilles. The guineaman (Cypselurus cyanopterus), a larger species occasionally occurs in the catch. Most other species are too rare, or small to be commercially important. The fish are captured with surface gill nets, handlines and dipnets after being lured near boats with tethered fish-attracting devices and chum. The fisheries and fishing methods in the various islands are reviewed by Mahon et al. (1986) and Oxenford et al. (1988).

There are no management regulations or policies relating to flyingfish. In the past few years, access by Barbadian fishing boats to flyingfish in the waters of Trinidad and Tobago has been an issue. An agreement was reached for the 1991 fishing season. The Eastern Caribbean Flyingfish Project (ECFFP) at Bellairs Research Institute, Barbados is the focus for research on flyingfish in the Lesser Antilles.

3.5.2 Stock structure, migration, dispersal

The catch rates of H. affinis in the eastern Caribbean are sharply seasonal. The fishing season extends from October to July, with a major peak around May and indications of a minor peak which may occur somewhere between November and February (Mahon et al., 1990). Although there are minor differences, the seasonal pattern is similar among islands. The fish are consistently unavailable to the fisheries in August and September. This seasonality could result from several mechanisms. Three hypotheses have been proposed, and are being evaluated by the ECCFP:

- eastward spawning migration from the central Caribbean Sea, through the island arc, into the Atlantic Ocean, with subsequent passive westward drift of eggs, larvae and juveniles;
- seasonal spawning aggregation, and consequent availability to the fishing gear at that time;
- a high level of post-spawning mortality such that the period of apparent low abundance is an interval between the availability of generations to the fishery.

The presence of a sequence of life-history stages in the waters off Barbados throughout the year does not support the hypothesis of a large-scale natant-contranatant migratory pattern (Lao, 1989). Tagging studies indicate that there is movement of flyingfish within the southeastern Caribbean in a single fishing season, and suggest that there is a single stock of flyingfish in this area (Figure 10) (Oxenford, 1992).

Information on local movements of H. affinis was obtained by tagging nearly 2,000 individuals off the west and southwest coasts of Barbados (Lewis, 1964). About 4.4% of the tagged fish were recaptured, mostly within a week of release, but some up to 3 months later. The results suggest that flyingfish to the east of Barbados follow the direction of the prevailing currents from east to west around the north and south coasts. On the west side of the island they exhibit a circular movement, either clockwise or counter-clockwise, which tends to retain them near the island off the western coasts. This circular movement parallels the behaviour of slowly revolving eddies of water which form on the western side of the island.

3.5.3 Biology and ecology

Growth

Length-frequency histograms of commercial catch suggest that H. affinis reaches full size and sexual maturity within one year (Lewis et al., 1962). Analyses of monthly length-frequency distributions of fish taken from commercial catch and from the stomachs of dolphin fish indicate that flying fish grow to about 197 mm in 12 months, that males reach sexual maturity at about 13 months, and females at about 15 months (Storey, 1983). The maximum observed size (about 30 cm) suggests that this species does not live past 18 months.

Work in progress on growth rates of juveniles indicates that there are daily growth rings in otoliths which can be used to estimate growth and longevity (Oxenford, 1989).

Reproduction

In the eastern Caribbean H. affinis are surface-schooling, particularly during the spawning season when they frequently aggregate around floating objects on which they deposit their eggs. Spawning extends from at least October through to July,

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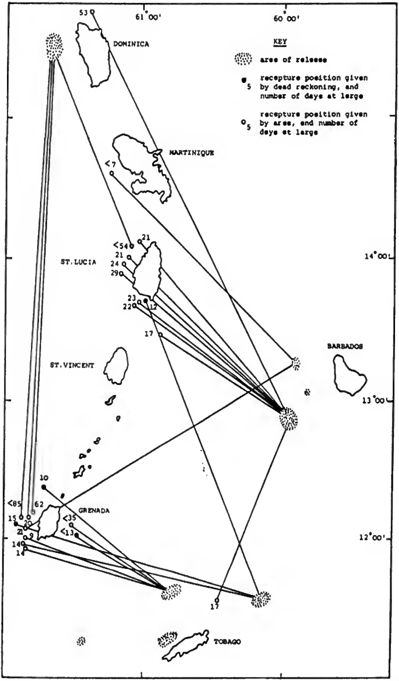

Fig. 10. Release and recapture of tagged flying fish in the southeastern Caribbean in the 1988 fishing season (Oxenford, 1992)

with a minor peak in December and a major peak in April (Lewis et al., 1962; Storey, 1983; Khokiattiwong, 1989).

The number of mature eggs produced by H. affinis in the vicinity of Barbados ranged from 4,100-9,200 for fish in the size range 196-233 mm (Hall, 1955). Egg diameter ranged from 1.30-1.78 mm. Size frequency analyses of oocytes indicate four distinct size classes, suggesting that each female may spawn four times within each season. Mean batch fecundity is 7,100 mature oocytes, giving a potential fecundity of about 28,500 oocytes per fish per season (Storey, 1983).

Early life history stages of H. affinis in the vicinity of Barbados have been described (Evans, 1961). Neuston nets and nightlighting throughout the year off Barbados took early life history stages of many flyingfish species. Juveniles of H. affinis appeared in December-January, and increased in abundance through to August (Lao, 1989).

Feeding

Stomach analyses suggest that feeding takes place primarily at night and that larval fish and larger zooplankton are the primary diet components (Hall, 1955; Lewis et al., 1962).

3.5.4 Stock assessment

Analysis of the time-series of catch and effort data for H. affinis from Barbados showed a steady upward trend which was assumed to be due to increased fishing power of launches. Thus, it was not possible to evaluate temporal trends in abundance. The interannual variability in the detrended time-series was among the highest for all pelagic species in the southern Lesser Antilles, as might be expected for a small, short-lived, pelagic species (Mahon et al., 1990; Mahon, 1990b).

The detrended time-series shows that recruitment tends to be low at the lowest levels of parent stock (Mahon, 1990b). However, there is a considerable proportion of unexplained variability in recruitment. The residuals around the stock recruitment relationship were weakly correlated with temperature, but not with other individual or composite environmental variables (Mahon, 1990b). The interannual variability in recruitment of H. affinis makes it unlikely that a steady MSY can be established for this fishery. Instead, as indicated by an analysis of the effects of different harvesting policies, increasing exploitation will carry an increasing risk of collapse (Mahon, 1989). Thus management would be a matter of establishing acceptable levels of risk.

Another aspect of the potential yield of H. affinis, is the extent to which there are significant quantities of flyingfish outside the area currently fished. This information would allow extrapolation from catches and exploitation rates inside the fished area to the entire area occupied by the stock (Oxenford et al., 1988). This approach, although very approximate, should provide a useful indication of the scope for expansion.

Distribution and abundance of adult and juvenile flyingfishes in the southeastern Caribbean were surveyed by visual counts, nightlighting, and neuston tows (Oxenford, 1988; Oxenford _et al._, in press). Abundance did not decrease markedly towards the edge of the survey area, suggesting that there may be a significant proportion of the stock outside this area.

3.5.5 Future directions

Better understanding of the factors responsible for the interannual variability in catch rates would improve the ability to predict the response of the stock to increased exploitation. The possibility that availability of floating material as a spawning substrate might limit recruitment has been considered. However, the failure of the survey to find floating material and eggs in areas of high abundance of adult fish during the peak spawning period has raised numerous questions regarding the spawning behaviour of _H. affinis_. Experiments to examine the possible use of alternative spawning substrates, and the extent to which floating material may be submerged by eggs, are in progress (Oxenford, 1989).

Surveys aimed at examining the distribution of flyingfish outside the area surveyed by the ECFFP will be needed to determine the extent to which _H. affinis_ are distributed outside the area currently fished.

3.6 Coastal pelagics

3.6.1 Overview of the fishery

A variety of small pelagic fishes with various life-histories, e.g., small schooling clupeids, jacks, and ballyhoo, as well as small tunas, and juveniles of larger tunas and tuna-like fishes, are exploited primarily by beach seines, gill nets and cast nets. The species composition of catches of small coastal pelagics has only been reported from a few islands. The main species from seine catches are: ballyhoo (_Hemirhamphus_ spp.), small jacks (_Caranx_ spp.), scads (_Selar_ spp.), and robins or scads (_Decapterus_ spp.). Small tunas, and the young of large tunas, such as yellowfin, may also be caught. The main species taken in small seines and cast nets are sardines, herrings, pilchards, anchovies, thread herrings and silversides (Clupeiformes, Atherinidae), known as fry, fray, and sprats.

The beach seine fishery is the most important, and may contribute as much as 30% of total catch in some islands. Less important are the bait fisheries for small schooling clupeids and similar species listed above, and gill-net fisheries. Further details of the gear, fishing practices, and distribution of the catch in these fisheries in many Lesser Antilles islands is available in Mahon and Rosenberg (1988).

Some islands, notably Grenada and Barbados, report declining trends based on qualitative information. There are some time-series of data on landings, for example in Grenada, St. Vincent and Barbados, but the only analysis which evaluates trends in catches or abundance is by Finlay and Rennie (1985a).

The only current management measures for coastal pelagics are restrictions on seine mesh-size in St. Vincent, and on the hauling of ballyhoo nets which may only be taken up onto boats. In that island there are traditional practices regulating access to the resource. The first boat in a bay on a given day is allowed to complete its set before the next boat begins to set. Such practices may exist elsewhere, and indicate that community based conservation and management may be worth pursuing.

3.6.2 Stock structure, migration, dispersal

There is virtually no information on stock structure, distribution, and migration of these species in the Lesser Antilles. Except for the juvenile tunas, it may be appropriate to initially assume that the stocks are at least island shelf specific. Nonetheless, as for other species with planktonic early life history stages, dispersal between islands is possible. The extent to which such dispersal may affect recruitment is unknown.

3.6.3 Biology and ecology

The biology and population dynamics of these fishes have received little or no attention in the Lesser Antilles. In Grenada availability of coastal pelagics to the fishery was found to be seasonal, being greatest between March and October (Finlay and Rennie, 1985a). Moon phase did not appear to affect availability to coastal gear on a monthly time scale.

3.6.4 Stock assessment

There has been no assessment of coastal pelagic species in the eastern Caribbean. Several islands report that catches of coastal pelagics have declined in recent years. However, there is no documentation of the extent of the decline or the species involved. There do not appear to be significant stocks of any herring or herring-like fishes (Clupeiformes) in the Lesser Antilles. The abundance of the other coastal pelagics which are caught by beach seines is unknown. The relatively low total revenue from these fisheries in the region will probably preclude any intensive assessment program in the foreseeable future.

The UNDP/FAO exploratory fishing survey (Appendix 1) conducted a survey of live-bait using lift nets, lamparas and beach seines at 236 stations throughout the Lesser Antilles between 1967 and 1970 (Wagner, 1974) (Table 19).

Bullis and Roithmayr (1971) spent 17 nights in the Windward Islands making observations on the attraction of small schooling fishes to night lights and their susceptibility to capture by a 6 inch (1,500 gpm) pump. Submerged 1,000 w lights were used. Species showing direct positive response to various light intensities included Anchoa lyolepis, Anchoviella eurystole, Jenkinsia sp., Membras sp., Harengula clupeola, H. humeralis, and Chirocentrodon bleekerianus, all of which appeared in dense concentrations at various times during the observations. Species showing indirect positive response included Opisthonema oglinum, Decapterus macarellus, Trachurus sp., and several other carangids. All of these exhibited some degree of susceptibility to fish pump capture. Highest sustained catch rates were made at Grenada where in 1 hour 234 lb of anchovies and sardines were pumped at the rate of 900-1,800 fish per second.

Table 19. Bait fishes caught throughout Lesser Antilles (1 bucket represents about 2.5-3.0 kg of fish) (Wagner, 1974)

	Species						
Locality	AN	DH	PL	RS	SA	SI	TH
			Number of buckets				
St. Martin	0	0	0	0	0	2.0	0
St. Barthelemy	0	0	0	0	0	0	0
Barbuda	0	0	16.0	0	0	0	0
Guadeloupe	0	0	0	0	0	1.0	0
Dominica	14.0	0	9.0	0	0	0	0
Martinique	33.5	0	0	9.0	18.0	9.0	0
St. Lucia	15.0	0	15.0	0	59.0	25.5	29.5
St. Vincent	0	5.5	8.0	16.5	5.5	1.5	239.5
Grenada	49.0	799.0	916.0	35.0	0	0	0
Barbados	0	0	0	0	0	27.5	6.0
Grenadines	0	0	2.5	112.5	0	2.5	112.5
Carriacou	17.0	0	0	17.5	17.0	0	17.0
Petit Nevis	0	0	0	0	0	6.0	0
Union Island	0	0	11.5	0	0	0	0

AN = anchovy (Engraulidae); DH = dwarf herring (Jenkinsia); PL = pilchards (Harengula); RS = round scad (Decapterus); SA = sardine (Sardinella); SI = silversides (Atherinidae); TH = thread herring (Opisthonema)

3.6.5 Future directions

Although intensive application of standard survey and assessment techniques will probably not be feasible for these fisheries, there are several simple steps which could be taken to develop a minimum acceptable level of basic information. Catch and effort data will be of primary importance in assessing the status of these resources. This should include data on the relative importance of species in the catch, and on the seasonality of the catches of the various species.

Sampling for size composition of the catch by species would indicate the extent to which the catch consists of immature individuals. By comparing the mean size of fish in the catch to known growth curves, and to observed maximum sizes of individuals of the same species, it is possible to assess the extent to which growth overfishing may be occurring.

3.7 Sea Urchins

3.7.1 Overview of the fishery

Sea urchins support small-scale fisheries in several southern Lesser Antillean islands. Only one species, Trypneustus

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ventricosus, is currently harvested, by free and SCUBA divers. The gonads are a consumer delicacy in some islands, notably Barbados, St. Lucia and Martinique.

Owing to limited amounts of suitable habitat, sea urchin stocks are unlikely to be large enough to sustain extensive fisheries, and will be easily overfished. At present, the status of this resource is: overexploited in Barbados, showing signs of overexploitation in St. Lucia; lightly exploited in Grenada; occasionally exploited in the St. Vincent Grenadines; and unexploited in norther islands. Exploitation should be encouraged in islands where this resource is currently underexploited. Given the sedentary nature of adults, a likely characteristic of these fisheries is localised depletion. Therefore, the rate of development and spatial distribution of new fishing effort should be monitored.

Only Barbados and St. Lucia have regulations controlling the harvesting of sea urchins. In Barbados there was historically a closed season from May-August each year. Recently, there has been a two year moratorium on harvesting and the population is under surveillance to determine the impact of this measure. Based on the initial results of the survey, the closed season has been revised to January-August each year.

3.7.2 Stock structure, migration, dispersal

There are no studies of stock structure of this species, or of the extent of egg and larval dispersal between islands. However, a stock structure study is in progress at UWI, Barbados. Adults are clearly restricted to island platforms and probably spend their entire lives within a radius of 1 km. However, there is the potential for genetic mixing, and recruitment interdependence among islands due to planktonic dispersal of early life-history stages.

3.7.3 Biology and ecology

The only published study of the biology of T. esculentus in the Lesser Antilles is from Barbados (Lewis, 1958). Juvenile urchins settle from the plankton in August and September of each year, and their test diameter is then between 1 and 3 cm. They reach sexual maturity and spawn in June, July, and August of the following year, when their test diameter ranges from5 to 8 cm. The length of larval development from fertilized egg to mature pluteus is estimated at only one month, but all attempts to rear larvae in the laboratory were unsuccessful.

T. esculentus feeds primarily on algae, with a preference in the laboratory for broad leafy algal forms such as Padina and Dictyota sp. However, the gut of numerous specimens examined contained only fine particles of calcareous sand, suggesting that the species may also be a detritus feeder.

3.7.4 Stock assessment

The decline of the sea urchin fishery in Barbados has been of national concern for the past two decades. There has been no assessment of the status of the resource. However, a survey of fishermen and consumers in 1986, documented their view of the decline, and its socioeconomic impacts (Scheibling and Mladenov, 1987). The survey indicated that overfishing was the cause of the decline, which began on the south and southeast coasts in the 1970s and spread to the east coast in the 1980s.

Current observations suggest that sea urchins recruitment is highly variable. Studies which characterise the relationship between the availability of recruits for settlement and the size of the parent stock are in progress. It is possible that juveniles prefer to settle in areas where adults are already established (Hunte, pers.comm.). Thus, although recruitment overfishing may not occur in the usual sense, depletion of adult stocks may inhibit settlement. Transplant studies are in progress to resolve this question.

3.7.5 Future directions

The parameters for yield per recruit analysis, growth, mortality, age/size at recruitment, can be estimated for T. esculentus, and such analysis could contribute to size limits, or effort limitation. Such regulations would be costly to enforce. Furthermore, habitat selection by settling juveniles and possible attracting effects of adults may be more important considerations in sea urchin management (Hunt, pers.comm.). Research in progress at Bellair Research Institute is addressing these issues.

Survey estimates of biomass and recruitment are feasible for this species. Thus, with mapping of suitable adult habitat for an island, potential yield could be estimated, and revised annually based on rapid surveys of the strength of the incoming year class. However, the costs of these approaches must be weighed against the value of the resource.

3.8 Other Resources

3.8.1 Turtles

Marine turtle populations in the western Atlantic are considered to be severely overexploited, and in some cases threatened with extinction. Despite widespread efforts to reduce exploitation, fishing continues in most islands of the Lesser Antilles.

Four species of marine turtles commonly occur in the Lesser Antilles:

leatherback	Dermochelys coriacea
green	Chelonia mydas
hawksbill	Eretmochelys imbricata
loggerhead	Caretta caretta

Between 1983 and 1987 WATS (the Western Atlantic Turtle Symposium) played the leading role in sea turtle conservation and management in the western Atlantic. Subsequently, WIDECAST, the

Wider Caribbean Sea Turtle Network has been coordinating conservation activities (Eckert, 1991).

Despite the moratorium called for by WATS and the OECS harmonised fishery regulations, turtles are regularly harvested in most eastern Caribbean islands. The catch is almost entirely green and hawksbill turtles. They are most often taken by turtle nets (large-mesh tangle nets), spearguns, and on beaches while nesting. The flesh is eaten and the shells are sold. Turtle eggs are also taken from nests for human consumption.

Current regulations include a closed season in most countries during the nesting period (March-July), and minimum size or weight limits. Taking eggs from, or disturbing nests is prohibited. In some countries turtles cannot be taken within 100 yards offshore. In several islands, the sale of turtle shell products is prohibited.

Sea turtles are long-lived and very late maturing. They nest on beaches, and the eggs and hatchlings are vulnerable to a variety of predators. Marine turtle populations are particularly dependent on appropriate beach sites for nesting. Coastal development has had a tremendous impact on the availability of suitable beaches for nesting. These impacts range from total destruction due to coastal structures, through disturbance of turtles in the act of nesting, to disorientation of hatchlings by artificial lighting. Conservation of suitable beaches is therefore of vital importance.

There is no stock assessment in the usual sense for any species of turtle. Most research efforts have been oriented towards conservation and acquiring the basic information required for conservation and rebuilding of stocks. This activity is being promoted and coordinated by WIDECASTE, for 39 countries in the wider Caribbean, including all Lesser Antilles countries. A primary output of WIDECASTE is national Sea Turtle Recovery Action Plans (STRAPS), tailored specifically to local circumstances (Eckert, 1991). STRAPS have been completed, or are in preparation for the following Lesser Antillean countries: Barbados, British Virgin Islands, Netherlands Antilles, St. Lucia, St. Vincent and the Grenadines, and the US Virgin Islands.

3.8.2 Shrimps

Marine shrimps are not an important resource in the Lesser Antilles, but are harvested from mangrove lagoons and bays. There is no information on catches of shrimps. The only studies of shrimps in the Lesser Antilles were carried out in Guadeloupe. These include biometry and growth of young Trachypenaeus shrimps, T. similis similis and T. constrictus in Guadeloupe (Rojas-Beltran, 1980). Growth was determined from weekly distributions of size classes, which are in generally polymodal. The von Bertalanffy growth equation is: $Tl = 87.48\ (1-e^{-0.1218t})$

Rojas-Beltran (1981) also estimated growth parameters for three species of Peneidae, on the basis of one thousand juveniles (total length between 12 and 80 mm) of: Penaeus aztecus subtilis, P. (Melicertus) brasiliensis, P. duorarum notialis, caught with a small trawl net and a Mediterranean fishing net in the mangrove swamps of Guadeloupe.

The ratios (total length (tl)/cephalothoracic length (cl), uropodal length (ul)/cl, abdomen length (al)/cl) differ very little for these three species, and the weekly growth of the three species combined can be expressed by Von Bertalanffy's equation: $tl = 197.75\ (1 - e^{0.04082t})$, where length is in mm and t is in weeks. Rojas-Beltran (1977, 1978) also describes the lagoon phase of penaeids in Guadeloupe.

3.8.3 Mammals

Through most of the 19th century American whaling vessels took whales in the Windward Islands, primarily humpback whales. These activities declined sharply after 1870. Locally, whaling remained important into the first two decades of the 20th century (Adams, 1971). Two kinds of whaling were practised in the Lesser Antilles; one for humpback whales or occasionally sperm whales, was restricted to Bequia (St. Vincent Grenadines); the other was for the blackfish or pilot whale (*Globicephala macrorhyncha*) (Caldwell and Caldwell, 1971). There is no whaling in the northern Lesser Antilles.

Caldwell and Caldwell (1975) reported that humpback whaling, and fishing for smaller cetaceans in the West Indies and Caribbean was on the decline, mainly due to economic factors. These are reduced interest by potential fishermen, general world inflation, the world energy crisis, and the recently enacted US Marine Mammal Protection Act of 1972. Catch statistics are tabulated for pilot, killer, false killer, and sperm whales, along with landed weight for mixed catches of dolphins. The pilot whale fishery of St. Vincent took 2,912 blackfish (*Globicephala macrorhynchus*) in the period 1962-74 (mean 224 per annum). Catches occur in all months, but are lowest in December and January. Ten other species of smaller cetaceans known to be taken in the waters of St. Vincent are the false killer whale, *Pseudorca crassidens*, small sperm whales, *Physeter catodon* Linnaeus, the pygmy killer whale, *Feresa attenuata*, the dwarf sperm whale, *Kogia simus*, the goosebeaked or Cuvier's beaked whale, *Ziphius cavirostris*, the rough-toothed dolphin, *Steno bredanensis*, the Risso's dolphin, *Grampus griseus*, the Atlantic bottlenose dolphin, *Tursiops truncatus*, the spinner dolphin, *Stenella longirostris*, and the bridled dolphin, *Stenella* cf. *S. frontalis* (G. Cuvier).

In St. Lucia, Gaskin and Smith (1977) report that Castries and Vieux Fort are the main centers, and Soufriere a secondary center. However, fishermen in most villages on the western and southwestern coasts take whales opportunistically. In October 1972 there were 12 vessels operating from Castries: one 50 ft, three 25 ft, and eight dugout canoes. The latter used hand-held harpoons but the larger boats had hand-made harpoon guns.

3.8.4 Sharks

Sharks and rays are a component of the fisheries treated under demersal and pelagic fishes. They are treated separately

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here because of certain distinctive characteristics, and because of a recent emphasis on improved fishing methods for sharks in Trinidad and Tobago, and Dominica. Close monitoring of the contribution of sharks to the catch in the other fisheries could indicate if a targeted fishery is warranted.

Sharks are generally large, long-lived and less fecund than other fishes. This combination of characteristics makes them susceptible to overexploitation at relatively low fishing mortalities. The biology of sharks is relatively poorly known. The fact that shark is not a preferred fish among consumers in the eastern Caribbean region, has deterred investment in fisheries specifically for sharks. However, with special programs to educate consumers in ways of preparing this low priced commodity, increased targeting for shark may be expected.

In the Lesser Antilles, sharks are caught incidentally by trolling for offshore pelagics, by trammel nets, and occasionally in trap and handline fisheries on the island shelves. In the latter case the catch is usually nurse shark. There are about 11 species of pelagic sharks commonly taken by longline and troll fishing in the eastern Caribbean. There are no data on species composition of demersal shark catches, but nurse sharks are considered to be the most common species taken (Mahon and Mahon, 1987).

3.8.5 Oysters

The only information on oysters from the Lesser Antilles pertains to Martinique. Most of the oyster beds in Martinique are along the Atlantic coast and in the bay of Fort de France (Saint-Felix, 1972). Crassostrea rhizophorae are mainly concentrated in the intertidal area of Rhizophora mangle roots, where spatial and trophic competition is lowest, as shown by the study of fauna and associated flora.

4. ACKNOWLEGDEMENTS

I would like to thank the individuals who responded to my request for papers: Richard Appeldoorn, Jim Beets, Mel Goodwin, Bertrand Gobert, Julia Horrocks, Wayne Hunte, Hazel Oxenford, Yvonne Sadovy. Thanks also to Wayne Hunte, Hazel Oxenford and John Neilson, for comments on sections of the manuscript.

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APPENDIX 1

DISPOSITION OF EXPLORATORY FISHING DATA FOR THE LESSER ANTILLES SUBREGION

The exploratory data collected by the FAO/UNDP Caribbean Fishery Development Project is maintained in several data files separated into various categories of information (Bullis, 1980). The common denominator linking these inventories together is the vessel station number. The basic data are station records, which provide all essential information on the particular fishing activity in terms of time and space, environmental parameters measured, and fishing effort and total catch in weights and/or numbers. The second type of file is made up of species records, one for each species captured or observed at a station. It includes locality and effort data and additionally provides total numbers and total weights. The third file is composed of biological information records. These have generally not been used extensively except in survey areas within USA coastal waters. Nevertheless, a small amount of biological data on the size frequency, sex ratios, etc., is available. The fourth file type consists of bridge observation records, and contains records of miscellaneous observations and captures which do not logically fit into the station card format. The types of information included are observations on sea birds, turtles, marine mammals, sharks, and surface schooling species. Seasonality of several of the open-ocean large pelagics such as Coryphaena, Acanthocybium, and small tunas and mackerels can be grossly plotted with the data in this deck. Also, all tuna school sightings can be found in this deck.

The Lesser Antilles (and Puerto Rico) are covered by Faunal zones 24-26 for which there are 140, 510 and 658 fishing stations (USA and FAO/UNDP) respectively. These data can be obtained in a variety of formats from the National Marine Fishery Service, Exploratory Fishing and Gear Research Base, Pascagnoula, Mississippi.

PART 2

PUERTO RICO AND HISPANIOLA

by

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ABSTRACT

A review of the marine fishery resources of Puerto Rico and Hispaniola islands is presented. It includes a description of the oceanography and physical characteristics of the islands, their coastline and surrounding seas. Detailed summaries of the biology and status of stocks of the most important species, including demersal and pelagic fishes, queen conch and spiny lobster. Special reference is made to the management of multispecies fisheries and shared resources and to the problem of ciguatera.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the technical assistance of Yvonne Sadovy and Daniel Matos of the Fisheries Research Laboratory, Puerto Rico Department of Natural Resources, for assistance in preparing portions of this report. Thanks are also due to Gladis Collazo for preparing figures.

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1. PHYSICAL DESCRIPTION OF THE AREA

1.1 Country Descriptions

The eastern-most region of the Greater Antilles contains three countries: Puerto Rico, the Dominican Republic and Haiti. The latter two share the island of Hispaniola; Puerto Rico is a commonwealth of the US. It shares its geological platform with the US Virgin Islands of Saint Thomas and Saint John, and with the British Virgin Islands. Puerto Rico falls within the Exclusive Economic Zone (EEZ) of the US Caribbean, which also encompasses the US Virgin Islands. Table 1 gives demographic and areal data for each country. Puerto Rico is one of the most densely populated areas in the Caribbean, but its population has been stable over the past few decades due to emigration to the US mainland. Haiti and the Dominican Republic are less populated, but actively growing. Haiti is considered to be the poorest country in the Western Hemisphere. In contrast, Puerto Rico has one of the highest standards of living in the Caribbean. Both Puerto Rico and Hispaniola are mountainous islands characterized by narrow insular shelves and steep insular slopes. To the north of Hispaniola, under the jurisdiction of the Dominican Republic, are several offshore banks (Figure 1). The largest of these are Silver Bank (3,710 km^2) and Navidad Bank (780 km^2), with three small ($\approx$50 km^2) banks between Silver and Navidad Banks, and another west of Samana Bay. There are a number of islands associated with each country; some are in areas of extended shelf, while others are located off the main insular platforms. The Dominican Republic has two islands on its southern shelf: Saona on the eastern end, and Beata on the western end. Gonave Island, on the western end of Hispaniola, is connected to mainland Haiti by a narrow stretch of shelf. Tortuga Island lies off Haiti's northern shelf, while the small Ile à Vache is located on Haiti's southern shelf near Les Cayes. Puerto Rico has two islands on its eastern shelf (Vieques and Culebra), and three small isolated islands in the Mona Passage (Mona, Monita, Desecheo). The EEZ of Puerto Rico and the US Virgin Islands extends 200 nm to the north and is bounded to the east by the EEZ of the British Virgin Islands, to the south by that of Venezuela, and to the west by that of the Dominican Republic. However, the US claims a different EEZ boundary line than does the Dominican Republic (Figure 1), and these differences have yet to be settled by treaty. The Dominican Republic's EEZ extends 200 nm to the northeast and elsewhere is bounded by the EEZs of Venezuela and Colombia (south), Haiti (west), and the Turks and Caicos Islands northwest). Haiti's EEZ is the smallest, being bounded by the EEZs of Colombia (south), Jamaica and Cuba (west), and the Bahamas Islands and Turks and Caicos (north).

1.2 Marine Habitats

Puerto Rico and Hispaniola contain a wide variety of coastal marine habitats, including coral and rock reefs, sea grass beds, mangrove lagoons, sand and algal plains, soft bottom areas, and sandy beaches. These habitats are, however, very patchily distributed. Along the north coast of Puerto Rico the insular shelf is very narrow (2-3 km wide), seas are generally rough, and

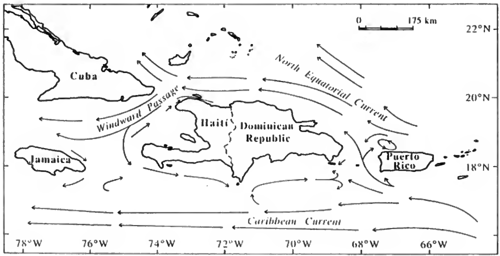

Fig. 1. General view of Puerto Rico and Hispaniola offshore banks showing insular shelves and offshore banks and boundaries of countries' Exclusive Economic Zones

few good harbours are present. The coast is a mixture of coral and rock reefs, sandy beaches. The east coast has an extensive shelf (44% of the total shelf) that extends to the Virgin Islands. Much of the bottom is sandy, commonly with algal and sponge communities and depth ranges from 18 to 30 m. The southeast coast has a narrow shelf (8 km wide). About 25 km to the southeast is Grappler Bank, a small seamount with its top at 70 m depth. The central south coast broadens slightly to 15 km and an extensive grassbed extends 9 km offshore to Caja de Muertos Island. Moving westward, the shelf narrows again to just 2 km before widening at the southwest corner to over 10 km. The whole of the southern shelf is characterized by hard or sand-algal bottoms with emergent coral reefs, grassbeds and mangroves inshore, and submerged reefs offshore and along the shelf edge. Along the southern portion of the west coast the shelf continues to widen reaching 25 km at its maximum. A broad expanse of shelf is found between 14 and 27 m; habitats are similar to those of the south coast. The southwest corner of Puerto Rico is one of the principal fishing areas due to the broad shelf, generally favourable seas and good harbours. Moving north, the shelf rapidly narrows to 2-3 km.

The north and south coasts of the Dominican Republic are similar to those of Puerto Rico. The northern shelf is very narrow with two exceptions. The first is Monte Cristo Bank at the western boundary of the country. The bank extends 20 km from shore and contains a wide expanse of shallow habitats, with small islets and coral reefs found near the western edge. This area is one of the more productive coastal fishing areas of the country.

The second area is Samaná Bay, also a productive fishing area. The bay is generally less than 50 m in depth and is estuarine at its western end where the Rio Yuna discharges into the bay. On the eastern tip of Hispaniola there is a narrow bank that extends some 30 km into the Mona Passage. The bottom here is rocky and seas are generally unfavourable for fishing. The south coast shelf, like that of Puerto Rico, is variable in width (generally 2-20 km). More extensive shelf areas are located at the eastern end around Saona Island, toward the centre of the coast near Ocoa Bay and Baní, and at the western end around Beata Island where the shelf extends out 35 km. These areas are less than 30 m deep and contain much coral and hard bottom habitats.

The insular shelf around Haiti is very limited. The only broad shelf areas are located west of Cape Dame Marie off the southern peninsula (extending 20 km), and between Gonave Island and Port-au-Prince. Moderate shelf areas (10 km) are found off of Gonaives Bay on the west coast, and in the vicinity of Les Cayes on the south coast. Coral and rock reefs are common along much of the Haitian coastline.

1.3 Climatic and Oceanographic Characteristics

The northeast Caribbean is characterized by a tropical terrestrial and marine environment. Summer air temperatures average 28°C, while winter temperatures average 24°C. Cooler temperatures are experienced at higher elevations. Annual rainfall throughout the region is variable. In Puerto Rico it can range from >500 cm in the eastern mountains to <12 cm in the southwest. In Hispaniola it ranges from over 250 cm to less than 12 cm, with higher values in the northeast and mountainous areas. Much of Haiti lies in the rain shadow of Hispaniola. The local variability of rainfall in the region is such that areas within 20 km may experience a five-fold difference in rainfall.

Rainfall is seasonal, with peaks in the late spring-early summer and again in late summer with the onset of the tropical storm season. Winds over the area come from the northeast, but are locally modified by land and sea breezes. Thus, winds along the south coasts of Puerto Rico and Hispaniola are generally from the southwest. Regionally, winds are strongest during the spring and summer, and lightest during the fall and winter. However, winds associated with the passage of tropical waves and storms during the fall can be strong and last several days.

Sea conditions generally reflect wind conditions. Waves are generally higher along the north coasts, where sea breezes reinforce the northeast trade winds. The north coasts also are subject to larger waves generated elsewhere in the North Atlantic, particularly during winter months. Sea conditions periodically worsen during the late summer and fall with the passage of tropical storms. Tidal regimes vary between the north and south coasts of Puerto Rico and Hispaniola (Kjerfve, 1981). The south coasts experience a diurnal tide of small amplitude: less than 10 cm for Puerto Rico and the Dominican Republic, 10-20 cm for Haiti. The west coast of Hispaniola and the north coasts of both islands have a mixed semidiurnal regime, with maximum fluctuations between 60 and 100 cm along the north coasts and 40-50 cm to the west of Hispaniola. Water temperatures follow a seasonal cycle, with maximum temperatures (28.5°C) occurring in August-September and minimum temperatures (25°C) occurring in February-March. Inshore, maximum temperatures may reach as high as 30°C. Temperatures are slightly warmer to the south than to the north of the islands, with the maximum difference of 1.4°C occurring during winter.

Current flow in the region is complex (Figure 2), but is generally bounded by two west flowing currents: the north branch of the Caribbean Current to the south, and the North Equatorial Current to the north. The north branch of the Caribbean Current flows westward at an average speed of 0.5 to 1 knots. It is located about 100 km south of the islands, but its position varies seasonally. During the winter it is found further to the south than in summer (Wust, 1964; Grant and Wyatt, 1980). Flow along the south coast of Puerto Rico is generally westerly (Yoshioka et al., 1985; Colin and Clavijo, 1988); off Hispaniola an eastward counter-current flows (Roemmich, 1981). This is set up by gyres formed between the Caribbean Current and the island (Wust, 1964; Nelepo et al., 1978). The main eastward flow is found about 40 km offshore and averages 0.5 kt (Fiedler et al., 1947). This flow is favoured during the winter with the greater distance between the coast and the west-flowing Caribbean Current (Wurst, 1964; Grant and Wyatt, 1980).

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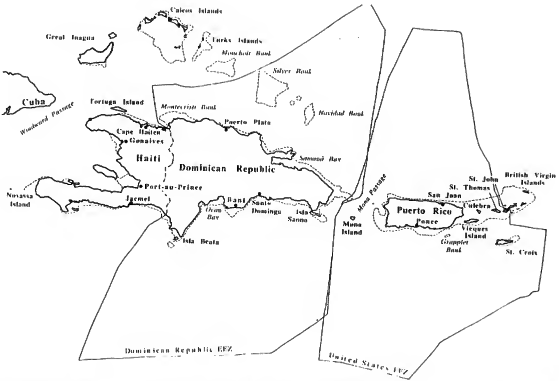

Fig. 2. Overview of Puerto Rico and Hispaniola showing predominant current flow. Figure more closely documents conditions occurring in winter

The North Equatorial Current flows westward along the north coasts of both islands. North of the Mona Channel it splits, with one branch flowing north of Silver and Navidad Banks, past Turks and Caicos to form the Bahamas Current. The southern branch stays along the north coast of Hispaniola about 30 km offshore.

Nearshore currents are generally westward, with a strong flow (1 knot) found north of Haiti were flow is restricted through the Tortuga Channel (Fiedler et al., 1947). A small gyre has been documented off the northwest corner of Puerto Rico resulting in an east flow nearshore in this area.

Flow through the Mona Passage is variable and affected by local tidal flow. Usually net surface currents flow to the northwest (Metcalf et al., 1977, Duncan et al., 1977), with this tendency being stronger during the summer. In the Windward Passage there is a strong flow southwest into the Caribbean. The main flow is located on the west side of the passage. Along the east side of the passage a northwest flowing countercurrent exists (Roemmich, 1981, Nof and Olson, 1983; Paskarsky and Nowlin, 1978; Gunn and Watts, 1982).

Primary productivity within the region is low, as found elsewhere in the Antilles. To the north of the islands rates average about 55-90 gC/m^2/yr. To the south rates vary between 37-55 gC/m^2/yr. An exception to the above is a low seasonal upwelling that occurs to the south of the Mona Passage during the summer (Bogdanov et al., 1968). This results in an increased phytoplankton abundance, to 100-300 mg/m^3, to the southwest of the Mona Passage compared to levels of 50-150 mg/m^3 elsewhere. Extremely low phytoplankton concentrations are found in the Windward Passage.

2. FISHERY RESOURCES

The review of fishery resources will be divided into four sections, each dealing with a separate component of the fishery. These components are as follows: demersal finfishes, pelagic finfishes, spiny lobster, and queen conch.

Catch data presented in this section are as reported in FAO Yearbooks of Fishery Statistics (for Haiti and the Dominican Republic) and as obtained from reports of the Puerto Rico Fisheries Research Laboratory, Department of Natural Resources. For all data sets the validity of reported figures is unknown. For Haiti and the Dominican Republic (FDL, 1980) they are particularly suspect. Data for Haiti are not based on actual landings surveys. Nevertheless, the broad trends revealed by these data are felt to be real.

For Haiti no breakdown of catch data is available other than for estimates of spiny lobster. This precludes any detailed analysis of the various components of the Haitian fishery. Table 2 summarizes estimates of total landings for all marine resources.

Table 1 Population and areal data for Puerto Rico, the Dominican Republic and Haiti

	Haiti	Dominican Republic	Puerto Rico
Land Area (km^2)	27,750	48,735	8,860
Population	6,200,000	5,500,000	3,600,000
Population Density (km^{-2})	223	113	406
Shelf Area (km^2)			
Insular	3,500	8,400	5,700
Offshore Banks		4,600	
Coastline (km)	2,040	1,350	540
Area of EEZ (km^2)		238,000	

Table 2 Estimated landings (mt) from Haiti for all marine fishes. Source: FAO Yearbooks of Fishery Statistics

Year	Catch	Year	Catch
1971	2100	1980	3600
1972	2100	1981	3600
1973	2100	1982	3600
1974	2100	1983	5950
1975	2100	1984	6450
1976	2100	1985	6950
1977	3600	1986	7450
1978	3600	1987	7500
1979	3600	1988	7500

Not included in the review below is the shrimp fishery of the Dominican Republic, the only significant shrimp fishery within the region. This fishery is located in Samana Bay and is pursued by fishermen working from small boats or canoes (FDL, 1980).

2.1 Demersal Finfishes

2.1.1 Overview of the fishery

Demersal fishes exploited in Puerto Rico and Hispaniola are those typically associated with tropical reef and hard bottom environments. Dominant taxa include the snappers (Lutjanidae), groupers (Serranidae), grunts (Haemulidae), parrotfishes (Scaridae), triggerfishes (Balistidae), and goatfishes (Mullidae). Many species are also common components of mangrove systems (especially as juveniles), seagrass beds, and open sand/algal plains. The demersal community can roughly be divided at about 50 m depth into shallow (shelf) and deep water (slope) components.

Principal gears for exploiting demersal resources are traps and hook-and-line; however, other gears such as gillnets, trammel nets, spears, bottom longlines, and beach seines are also important. Traps are the most important gear in Puerto Rico, the Dominican Republic and Haiti, particularly for shallow water species. They are also used in deepwater where currents and bottom slope permit deployment. In Puerto Rico, the use of traps relative to other gears has sharply declined (Matos and Sadovy, 1990). Traps in Puerto Rico and the Dominican Republic are variable in size, framed in mangrove or re-enforcing rod, with typically chicken wire for the mesh, although vinyl-coated rectangular wire is becoming more popular. Mesh size is variable but is generally small, significantly less than the 50 mm estimated to maximize catch. The dominant trap design in Puerto Rico is the chevron or arrowhead trap with a single opening, while in the Dominican Republic the Z-trap, with two openings, dominates. In Haiti, most traps are of the chevron design, constructed of woven bamboo without framing, and are thus smaller and less durable than those found elsewhere.

Hook and line fishing is either by hand or by the use of power "snapper" reels. The former is dominant in Haiti and common in the other two countries. The use of snapper reels is dominant in the Puerto Rican and Dominican deepwater fisheries and is also common in many deeper areas of the shelf.

Although gillnets and trammel nets are typically associated with pelagic fisheries, they are often set close to reefs or on the bottom, which thus often results in significant catches of demersal fishes (Acosta, unpublished data). Net designs are quite variable. The relative use of these nets in Puerto Rico has increased significantly in recent years (Acosta, 1992), both in number and length of net.

In Haiti, the fishery is pursued from small, sail-powered boats, and canoes of limited range and sea-worthiness (Brethes and Rioux, 1986). In the Puerto Rico and Dominican fisheries, boats can be classified into two types (Weiler and Suarez-Caabro, 1980; FDL, 1980). Small, commonly from 4 to 6 m in length, outboard-powered boats with one or two fishermen are used by the majority of fishermen. These boats can range generally over the entire insular shelf. Larger (greater than 7 m) inboard diesel-powered boats are used for fishing the shelf-edge and offshore areas. Trips last from one day to several weeks. These boats are typically equipped with several power reels for hook and line fishing and/or powered pot-haulers for fishing strings of traps. Several larger boats and ships have been employed in the Dominican Republic for fishing off Silver and Navidad banks.

Fishing is conducted in all areas of the shelf, with areas where the shelf is widest being the most important. In Haiti, areas of deep water or far from port are only lightly fished; this is due to poor boat handling over open water, and the lack of capital available to fishermen, who are reluctant to risk investment or gear loss (Stickney and Kolher, 1986; Brethes and Rioux, 1986). In the south of Haiti, the small number of good harbours restricts fishing in this area. In Puerto Rican and Dominican waters most deepwater slope areas and offshore banks have been thoroughly exploited, with Silver and Navidad Banks being of primary importance. A number of boats from both countries actively fish in foreign waters, particularly in Turks and Caicos to the north, and Saba Bank to the southeast. It should be noted that such foreign catches are not typically recorded as such in landings statistics.

Reported estimated landings of demersal fish groups in Puerto Rico and the Dominican Republic are given in Tables 3 and 4. In Puerto Rico landings peaked in 1979 and have steadily declined since then to a level of about 20% of the 1979 landings. This decline has occurred in all species groups. In the Dominican Republic, landings have shown a general increasing trend. Peak landings in Puerto Rico (1979) and in the Dominican Republic (1987) represented similar levels of yield per shelf area, at 0.42 mt/km^2 each (including offshore banks).

In Puerto Rico, the composition of the landings trends has shown changes over time (Table 5). Grunts, principally the white grunt Haemulon plumieri, have steadily declined as a percentage of the catch, from about 25% to less than 10%. Similarly, groupers have declined slightly, from about 17% to 12%. Within the groupers, the principal grouper species is the red hind, Epinephelus guttatus, which represents about 30% of all groupers (46% by number) and 3.5% of all demersal fishes (Matos Caraballo and Sadovy 1990). Second in importance is the coney, E. fulvus, representing 32% by number of all groupers (Sadovy, pers. comm.). Smaller percentages are recorded for the rock hind, E. adscensionis, and the graysbe, E. cruentatus. The Nassau grouper, E. striatus, which was previously one of the most important commercial species (Sadovy and Figuerola, in press), now is rare and represents only 2% of all groupers and 0.2% of all demersals. Parrotfish have shown the greatest decline. Previously a significant component of the catch, they have dropped from 13% in the early 1970s to less than 1% in 1989, with the decline in the last few years being precipitous. In contrast, the percentage of snappers has increased, from about

Table 3 Estimates of annual landings (mt) of demersal fishes in Puerto Rico. Source: P.R. Fisheries Research Laboratory, Dept. Natural Resources

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Grunt	.	.	262.7	316.8	420.0	460.5	482.7	456.4	329.5	75.0
Hogfish	.	.	16.4	16.8	25.0	34.1	34.1	35.5	34.5	13.6
Trunkfish	19.1	19.1	9.1	10.5	13.6	28.2	35.9	35.9	32.3	22.7
Squirrelfish	34.5	36.4	11.8	9.1	30.0	49.5	50.9	32.7	22.7	6.8
Parrotfish	84.1	118.2	157.3	142.3	137.7	109.5	124.5	173.6	120.0	35.9
Grouper	172.3	151.8	148.6	193.6	241.4	292.3	382.3	447.7	337.3	197.7
Mojarra	0.5	0.0	3.2	7.7	7.7	10.9	12.7	10.0	14.5	10.5
Lane Snapper	51.8	47.7	48.2	50.5	55.9	68.6	167.7	175.9	130.9	90.9
Yellowtail Snapper	45.5	44.1	48.2	65.9	58.2	73.6	100.5	139.5	96.8	51.8
Silk Snapper*	176.4	115.9	120.9	217.3	190.5	167.7	248.2	340.5	389.5	316.4
Mutton Snapper	26.4	26.4	30.9	26.4	35.0	31.4	42.7	53.2	47.7	25.9
Other Snapper	20.9	25.9	20.9	20.0	30.9	35.0	32.3	47.7	44.1	31.8
Total Snapper	320.9	260.0	269.1	380.0	370.5	376.4	591.4	756.8	709.1	516.8
Triggerfish	84.5	80.5	55.5	34.1	35.0	45.0	49.5	66.8	75.0	26.4
Porgy	36.8	21.8	24.5	21.4	29.5	28.6	29.1	69.5	58.6	14.1
Goatfish	159.5	151.4	133.6	121.4	131.8	134.1	134.5	193.2	162.7	11.4
Other	9.5	53.6	93.6	82.7	72.3	85.5	135.5	123.6	151.4	807.7
Total Demersal Harvest	921.8	892.7	1185.5	1336.4	1514.5	1654.5	2063.2	2401.8	2047.7	1738.6

* Includes all deepwater snappers

	1982	1983	1984	1985	1986	1987	1988	1989
Grunt	200.5	193.6	165.5	143.2	86.8	76.8	42.3	35.9
Hogfish	32.3	37.3	34.1	21.4	.	21.8	15.0	11.8
Trunkfish	21.8	19.1	20.0	19.1	15.5	18.2	17.3	22.7
Squirrelfish	12.3	10.0	5.0	7.7	5.5	1.8	2.3	5.9
Parrotfish	127.7	105.5	110.9	108.6	46.4	33.6	5.5	1.8
Grouper	211.4	160.9	157.7	160.5	86.8	64.5	42.3	59.5
Mojarra	9.5	5.9	5.5	5.0	4.5	3.6	8.2	5.5
Lane Snapper	129.1	86.8	76.8	60.9	37.3	27.7	37.3	49.5
Yellowtail Snapper	89.5	81.8	66.4	77.3	44.1	45.9	35.5	41.8
Silk Snapper*	310.9	190.9	171.4	189.5	148.6	95.5	80.0	112.3
Mutton Snapper	31.8	31.8	27.7	23.2	13.2	8.2	10.0	14.5
Other Snapper	32.3	30.9	18.2	16.8	.	9.5	17.3	18.6
Total Snapper	593.6	422.3	360.5	367.7	243.2	186.8	180.0	236.8
Triggerfish	56.4	44.1	23.6	25.0	12.7	17.3	12.7	15.0
Porgy	43.2	37.7	31.8	12.3	8.2	5.0	4.1	4.5
Goatfish	71.4	75.9	60.9	27.7	9.5	4.5	3.2	4.5
Other	148.2	91.4	76.4	107.7	121.4	95.9	61.4	58.6
Total Demersal Harvest	1528.2	1203.6	1051.8	1005.9	640.5	530.0	394.1	462.7

* Includes all deepwater snappers

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Table 4 Reported landings from the Dominican Republic for demersal fishes and shrimp (in t). Source: FAO Yearbooks of Fishery Statistics

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Epinephelus spp.	203	140	195	114	88	71	110	90	99	146	97	188	303	207	246
Other Serranids	486	517	503	415	447	736	826	1095	282	252	1275	625	1232	2123	1931
Total Groupers	689	657	698	529	535	807	936	1185	381	398	1372	813	1535	2330	2177
Red Snapper	.	.	.	.	253	343	394	300	250	718	892	636	403	428	389
Yellowtail Snapper	.	.	.	.	182	285	321	320	202	276	254	155	210	191	174
Other Snapper	202	143	173	92	113	236	259	389	131	170	166	101	73	68	62
Total Snappers	202	143	173	92	548	864	974	1009	583	1164	1312	892	686	687	625
Grunts	.	.	.	.	.	.	.	.	403	368	400	686	600	509	463
Other Demersal	616	468	563	381	661	959	1078	1287	1104	1439	1697	2099	2102	1905	1674
Total Demersal	1507	1268	1434	1002	1744	2630	2988	3481	2471	3369	4781	4490	4923	5431	4939
Shrimp	107	100	70	65	108	367	821	635	472	348	398	155	198	307	279

Table 5. (A) Landings of grunt, grouper, and snapper in Purto Rico as a percentage of total demersal catch, and (B) landings of snapper species as a percentage of total snapper catch

A.	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Grunt	.	.	22.16	23.71	27.73	27.83	23.40	19.00	16.09	4.31	13.12	16.09	15.73	14.23	13.55	14.49	10.73	7.76
Grouper	18.69	17.01	12.54	14.49	15.94	17.66	18.53	18.64	16.47	11.37	13.83	13.37	15.00	15.95	13.55	12.18	10.73	12.87
Snapper	34.81	29.12	22.70	28.44	24.46	22.75	28.66	31.51	34.63	29.73	38.85	35.08	34.27	36.56	37.97	35.25	45.67	51.18
B.																		
Lane Snapper	16.15	18.36	17.91	13.28	15.09	18.24	28.36	23.24	18.46	17.59	21.75	20.56	21.31	16.56	15.34	14.84	20.71	20.92
Yellowtail Snapper	14.16	16.96	17.91	17.34	15.71	19.57	16.99	18.44	13.65	10.03	15.08	19.38	18.41	21.01	18.10	24.57	19.70	17.66
Silk Snapper*	54.96	44.58	44.93	57.18	51.41	44.57	41.97	44.98	54.94	61.21	52.37	45.21	47.54	51.55	61.10	51.09	44.44	47.41
Mutton Snapper	8.22	10.14	11.49	6.94	9.45	8.33	7.23	7.03	6.73	5.01	5.36	7.53	7.69	6.30	5.43	4.38	5.56	6.14
Other Snapper	6.52	9.97	7.77	5.26	8.34	9.30	5.46	6.31	6.22	6.16	5.44	7.32	5.04	4.57		5.11	9.60	7.87

* Includes all deep-water snappers

25% to 50% since 1972. Within the snappers, there has been no general change in species composition over the past 15 years. Deepwater snappers form the largest component, varying from about 45% to 60% of all snappers. Principal species here are the silk snapper, Lutjanus vivanus, the vermillion snapper, Rhomboplites aurorubens, the queen snapper, Etelis oculatus, and the blackfin snapper, L. buccanella. The shallow water lane snapper, L. synagris, and yellowtail snapper, Ocyurus chrysurus, each comprises about 20% of the total snapper catch.

In the Dominican Republic, principal species groups are the groupers, snappers, and grunts representing 43%, 13%, and 9% of the demersal catch, respectively. The proportion of snappers has declined from a peak of 35% in 1983 to 13% of all demersal fishes. Important components here are the yellowtail snapper and the deep-water snappers (recorded in Table 4 as red snapper). Conversely, there has been an increase in the landings of groupers, from 15% in 1982 to 43% currently. As in Puerto Rico, the red hind is the principal grouper in the catch (FDL, 1980).

2.1.2 Stock structure, migration, dispersal

The stock structure of demersal fishes in this area has not been determined. The sedentary nature of most species would indicate little migratory activity by adults. No exchange of juveniles or adults would be expected between Puerto Rico and Hispaniola. For purposes of management, it has been assumed by the Caribbean Fishery Management Council (for the US Caribbean) that fishes on the Puerto Rico-Virgin Islands platform constitute a single stock.

Many species of reef fishes are known to move to progressively deeper water with age (e.g., grunts (Gaut and Munro, 1983)). In areas of extensive shelf this constitutes an ontogenic migration. Nevertheless, total distance travelled would not be great. Groupers and some other species are known to form spawning aggregations. For some species, e.g., Nassau grouper, these aggregations are quite large, and must represent a gathering of individuals over an extensive area. It is unknown whether there is any genetic continuity within spawning aggregations.

The effect of larval dispersal on stock structure is unknown. However, given that many species have larval durations of several weeks it is possible that genetic exchange occurs throughout the area.

2.1.3 Basic population biology

The biology of the various taxa of reef fishes cannot be easily generalized. Fishes show a wide range of habits, growth and mortality rates, and reproductive strategies and patterns in spawning activity. General reviews for snapper and groupers worldwide are given in Polovina and Ralston (1987); brief synopses for species in the region are given in Appeldoorn et al. (1987).

Within the region, quantitative aspects of population biology have only been studied for but a few of the many species represented in the demersal catch. All of these have been done in Puerto Rico. Reviewed here are estimates of growth and mortality for commercially important species, plus some comments on reproductive activity and, for deeper-water species, depth distribution.

Table 6 presents estimates obtained from the literature of von Bertalanffy growth parameters (L and k) and instantaneous natural mortality (M). Most growth parameters were obtained using length-frequency analysis. These values are consistent with those reported elsewhere (e.g., Munro, 1983). Table 7 gives length-weight conversions for a number of demersal species. These can be used to convert values of asymptotic length to asymptotic weight for yield-per-recruit analysis, or for converting length-frequency distributions and abundance estimates into biomass estimates.

Table 8 summarizes information on species composition by depth, and depth range for the most important species. The species composition with depth in Puerto Rico is similar to that reported in the table for the Dominican Republic. The various surveys represented in the table are in general agreement as to species-specific depth distributions. For Lutjanus vivanus, L. buccanella, and Rhomboplites aurorubens there is a trend for length-frequency distributions to be shifted to larger sizes with depth (Boardman and Weiler, 1980). Table 9 gives the known spawning seasons for various demersal species occurring in the fishery as determined from local observations. Two dominant patterns emerge. The majority of species seems to spawn during winter months. Most of the remaining species spawn year-round, either routinely or in a scattered manner. It is interesting to note that for one species, yellowtail snapper, there is evidence of different spawning patterns between northeast Puerto Rico and Silver Bank off the northern Dominican coast.

Special mention should be made of spawning aggregations. Such aggregations are known for many groupers and a few other species. In Puerto Rico spawning aggregations of the red hind, Epinephelus guttatus, have been documented: one on an offshore bank west of Mayaguez on the west coast (Rosario Jiménez, 1989), and two about 10 km apart on the southwest coast off La Parguera (Shapiro, 1987). One of the latter has been studied in some detail. The fish aggregate the week before full moon in January or February (Erdman, 1976; Shapiro, 1987). In 1984 there were an estimated 3,000 individuals, with a sex ratio of 4.5:1 (F:M), gathered at one time (Shapiro, 1987). Erdman (1967) reported that aggregations occurred almost every year; between 1954 and 1966, there were only two years (1957, 1965) when aggregations could not be found. A spawning aggregation for Nassau grouper, E. striatus, was documented of the east side of Mona Island, but this has since collapsed (Colin, 1982). Ocean surgeon, Acanthurus bahianus, has also been observed to form spawning aggregations. These form around full moon and have been observed to contain up to 7,000 individuals (Colin and Clavijo, 1988).

Table 6 Estimates of von Bertalanffy growth parameters and natural mortality rate for fishes from Puerto Rico

Species	L_{inf}	K	M	Source
Epinephelus guttatus	520		.59	1
(Red Hind)	514	.10	.23	2
Epinephelus fulva	340		1.31	1
(Coney)				
Ocyurus chrysurus	545	.10	.32	3
(Yellowtail Snapper)	534	.17	.44	3
Lutjanus synagris	450	.23	.53	4
(Lane Snapper)				
Haemulon plumieri	420	.26		1
(White Grunt)	370	.31	.77	5
	376	.34	.81	5
Haemulon flavolineatum	350	.24	.66	5
(French Grunt)				
Haemulon sciurus	371	.30	.75	5
(Bluestriped Grunt)				
Pseudupeneus maculatus	270	.28	.62	1
(Goatfish)				
Sparisoma aurofrenatum	260	.20		1
Redband Parrotfish)				
Holocentrus rufus	230	.29	.83	1
(Squirrelfish)				
Holocentrus ascensionis	300	.26	1.00	1
(Longjaw Squirrelfish)				

Sources: 1 - Stevenson (1978)
2 - Sadovy & Figuerola (In press)
3 - Dennis (In press, a)
4 - Acosta & Appeldoorn (unpublished data)
5 - Dennis (In press, b)

Table 7. Parameters for length-weight regressions for demersal fishes from Puerto Rico. Regression equation is of the form: Log_{10} (Wt) = a + b Log_{10} (FL). Units: Length (mm), Weight (g). N = Sample size. S = Literature Source

Species (Common Name)	Intercept (a)	Slope (b)	N	S
Balistes vetula (Queen Triggerfish)	-4.207	2.839	318	1
	-4.031	2.773	108	2
Ocyurus chrysurus (Yellowtail Snapper)	-3.176	2.339	959	1
	-4.727	2.972	144	2
Lutjanus synagris (Lane Snapper)	-4.488	2.875	386	1
Lutjanus analis (Mutton Snapper)	-4.830	3.024	51	1
Lutjanus apodus (Schoolmaster Snapper)	-5.086	3.148	69	1
Lutjanus vivanus (Silk Snapper)	-5.098	3.127	172	1
	-4.891	3.034	140	2
Lutjanus buccanella (Blackfin Snapper)	-4.416	2.859	20	1
	-5.123	3.146	130	1
Rhomboplites aurorubens (Vermillion Snapper)	-4.726	2.977	156	1
	-4.560	2.907	09	2
Epinephelus guttatus (Red Hind)	-4.669	2.391	681	1
	-5.226	3.140	2042	2
Epinephelus fulvus (Coney)	-4.632	2.926	553	1
	-4.892	3.303	1583	2
Epinephelus striatus (Nassau Grouper)	-5.167	3.136	58	1
Mycteroperca venenosa (Yellowfin Grouper	-4.703	2.976	19	1
Haemulon plumieri (White Grunt)	-4.265	2.819	1044	1
Haemulon sciurus (Bluestripped Grunt)	-4.626	2.965	134	1
Haemulon flavolineatum (French Grunt)	-3.894	2.666	195	1
Scarus taeniopterus (Princess Parrotfish)	-4.505	2.895	78	2
Sparisoma chrysopterum (Redtail Parrotfish	-4.676	2.982	78	1
Calamus penna (Pluma)	-4.137	2.799	576	1
Calamus bajonado (Jolthead Porgy)	-4.338	2.894	110	1
Lachnolaimus maximus (Hogfish)	-3.981	2.706	53	1
Mulloidichthys martinicus (Yellow Goatfish)	-4.863	3.050	85	1
	-5.238	3.289	78	1
Pseudupeneus maculatus (Spotted Goatfish)	-4.696	2.982	1140	1
Lactophrys polygonia (Honeycomb Cowfish)	-4.144	2.757	200	1
Lactophrys quadricornis (Scrawled Cowfish	-3.125	2.300	211	1
Holocentrus ascensionis (Longjaw Squirrelfish)	-4.861	3.055	159	2
Holocentrus rufus (Squirrelfish)	-3.802	2.561	90	2
Malacanthus plumieri (Sand Tilefish)	-5.109	2.976	734	2

Source: 1 - Bohnsack et al. (1986; Table 14a).
2 - Rosario Jiménez (1989)

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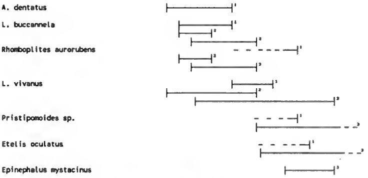
Table 8. Percent species composition by depth, and depth range for principal species as determined from fisheries independent surveys in the Dominican Republic and Puerto Rico. Composition by depth (upper part of table) is from FDL (1980).

	Depth (m)																				
Species	0		30		60		90		120		150		180		210		240		270		300
Haemulidae		32		35		23															
Epinephelus adscensionis		9		6		13		2													
E. guttatus		45		44		34		47		12		26		10							
E. fulvas		10		9								7				30					
Apsilus dentatus						19		23		64		28		43		24		62		20	
Lutjanus buccanella						5		7		6		15		37		41		8		60	
L. purpureus										14						12					



[1] Kawaguchi (1974). Hook and line survey: range of best catch.
[2] Boardman and Weiler (1980). Trap survey: range of best catch.
[3] Nelson and Appeldoorn (1985). Submersible-based visual census: observed range.

Table 9. Reported spawning seasons for demersal fishes of commercial value. All reports are for Puerto Rico except as noted. All reports from reference 1 are from southwest Puerto Rico and based on spawning observations. All others are based on frequencies of ripe or spent adults.

Species (Common Name)	Spawning Season	Source
Malecenthus plumieri (Sand Tilefish)	Dec-Mar	
Pseudupeneus maculatus (Spotted Goatfish)	Feb-Apr peak	1
Bodianus rufus (Spanish hogfish)	Scattered year-round, Low in summer	1
Scerus iserti (Striped Parrotfish)	Nov-March peak,	1
Scerus taeniopterus (Princess Parrotfish)	Scattered year-round	1
Sperisoma aurofrenatum (Redband Parrotfish)	Year-Round	1
Sparisoma viride (Stoplight Parrotfish)	Oct-Apr, Scattered	1
Acenthus bahienus (Ocean Surgeon)	Nov-Apr	1
Acenthus coeruleus (Doctorfish)	Most of the year	1
Archosargus rhomboidalis (Sea Bream)	Nov-Mar, peak Feb	2
Calamus pennatula (Piuma)	Feb-Mar	2
Calamus penna (Sheepshead Porgy)	Feb-Mar	2
Ocyurus chrysurus (Yellowtail Snapper)	Mar-May, Northeast PR Sept-Oct, Silver Bank	2
Lutjanus synagris (Lane Snapper)	Mar-Sept, peak in May	2
Lutjanus vivanus (Silk snapper)	Year-Round	3
Lutjanus bucanella (Blackfin snapper)	Year-Round	3
Rhomboplites aurorubens (Vermilion Snapper)	Year-Round	3
Epinephelus guttatus (Red Hind)	Jan or Feb at full moon	2,4

Sources: 1 - Colin and Clavijo (1988)
2 - Erdman (1976)
3 - Boardman and Weiler (1980)
4 - Shapiro (1987)

2.1.4 Assessment studies

The status of the demersal fish resources in Puerto Rico has been investigated through resource surveys and the use of stock assessment models, particularly yield-per-recruit. Table 10 summarizes catch and effort data from two surveys conducted off Puerto Rico 20 years apart. Due to differences in location fished, and gear and fishing tactics employed it is difficult to standardize the results between these two surveys. As a consequence, it is felt that little meaning should be attached to the higher catch rates reported in the more recent study. The recent survey clearly shows a trend of greater catch rates at further distances from the coast. This is probably reflective of the greater degree of fishing pressure in nearshore areas.

Boardman and Weiler (1980) reported on the results of a trap survey of deepwater species, primarily snappers. They attempted to compare their catch rates with previous surveys. Again differences in methodology made standardization difficult. They felt that there was evidence in these data for a decline in catch rates between the late 1960s and the late 1970s. However, in re-examining these data, as reported in Boardman and Weiler (1980), this conclusion is not readily apparent. Nevertheless, changes in fleet composition and increases in distance travelled to fishing ground occurred at this time, which would suggest that increased fishing pressure was reducing stock size (Boardman and Weiler, 1980).

A resource assessment survey of deepwater snapper and groupers based on visual census counts from a submersible was reported by Nelson and Appeldoorn (1985). This survey also include areas of the US Virgin Islands. Their density estimates are reported in Table 11. Using these estimates, catch rates for standardized, 364 m (1,200 ft) bottom longlines were estimated and compared to observed catch rates from 46 sets made at the same sites and time as the assessment transects. Predicted catch rates (Number/set) were 3.5 and 0.3 snappers and groupers, respectively. Observed catch rates were 4.4 and 0.3 snappers and groupers, respectively.

Yield per recruit analyses have been made for a number of species. Stevenson (1978) reported analyses for seven species off Puerto Rico's west coast during 1973-74 (see Table 6 for a list). At this time he found evidence of only slight over-exploitation in just the two largest species, the red hind and the white grunt.

Appeldoorn and Lindeman (1985) conducted a lumped-species Gulland-Fox surplus production model for all grunts (Haemulidae) in the trap fishery off La Parguera on the southwest coast. This analysis indicated that by the mid-1980s the grunts as a whole were being overfished. More specific yield-per-recruit analyses for three species of grunt were reported by Dennis (in press, a) using 1984-85 data from all of Puerto Rico. At this time he found the French and white grunts (Haemulon flavolineatum and H. plumieri) to be fully exploited, and the bluestripped grunt (H. sciurus) to be under-exploited. Significant shifts of length-frequency histograms to smaller sizes were noted, particularly

Table 10. Catch per effort (Kg/line/hr) reported from fishery independent surveys using hook and line. Numbers in parentheses are sample size (= number of 2 x 2 N mile quadrats). Sources: Kawaguchi (1974), FDL 1980), Rosario (1989).

	1967-68	1978	1988-89
DR Shelf		0.23	
Montecristi Bank	0.68	0.59	
Silver Bank	0.60	1.66	
Minor Banks	0.12		
Navidad Bank	1.11	3.42	
Mona Passage	0.10		1.64 (22)[1]
Mona			2.59 (9)
Banks & Desecheo			1.14 (8)
West PR Shelf-edge			0.74 (5)
PR Shelf-edge	0.31		0.81 (12)
PR South Coast[3]			0.77 (9)[1]
Inner shelf			0.25 (3)
Outer shelf			0.61 (2)
Shelf-edge	0.20		1.24 (4)
Grappler Bank	0.44		
PR North Coast[4]			0.36 (5)[1]
Shelf			0.35 (2)
Shelf-edge	0.15		0.36 (3)
PR West Coast			0.37 (24)[2]
Inner shelf			0.07 (8)
Outer Shelf			0.43 (11)

---

[1] Value is average of indented values immediately below

[2] Value is average of indented values immediately below and value for West PR shelf-edge

[3] Area is extreme west end for 1988-89, middle and extreme east end for 1967-68

[4] Area is extreme west end for 1988-89, extreme east end for 1967-68

Table 11. Density of snappers and groupers (number/100 m^2) by depth (A) and substrate type (B) observed on submersible surveys around Puerto Rico and the US Virgin Islands, 1985. [Modified from Nelson and Appeldoorn (1985); Table 4]

A	Depth Category (m)			
	450-360 (45)	360-270 (66)	270-180 (40)	180-90 (25)
All Groupers	0.000	0.000	0.016	0.950
All Snappers	0.082	0.202	1.361	2.228
Total	0.082	0.202	1.377	3.178

B	Habitat Type			
	Sand (100)	Sand-Rubble (35)	Rubble -Rock (18)	Rock Wall (23)
All Groupers	0.000	0.019	0.000	1.031
All Snappers	0.202	0.244	2.347	2.395
Total	0.202	0.263	2.347	3.426

Table 12. Data used and results of a Gulland-Fox surplus production model[1] of total catch of the Dominican fishery. Effort and catch are by km^2. Correlation (r^2) for the model regression = 0.92. Source: FDL (1980).

Location	Effort (boats)	Catch (mt)	CPUE
Monte Criste	0.10	0.84	8.40
Puerto Plata	0.32	1.33	4.16
Soana	0.42	2.20	5.24
Ocoa	0.49	1.92	3.92
Santo Domingo	0.56	1.77	3.16
Beata	0.64	2.33	3.64
Samana	1.48	1.86	1.26

MSY	2.25	mt/km^2
E_s	0.788	boats/km^2
U_s	2.85	mt/boat/km^2

[1] Model: Ln(CPUE) = a - b (Effort)

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for white grunt between 1974 and 1985 (Figure 3). A similar yield-per-recruit analysis on yellowtail snapper (Dennis, 1991) showed this species also to be fully exploited in 1984-85.

Finally, Sadovy and Figuerola (in press) reported on a yield-per-recruit analysis of the red hind (Figure 4). They found current fishing pressure ($F = 0.31$, 1988) to be close to that predicted for Maximum Sustainable Yield (MSY), but it was also 50% greater that predicted for optimum yield using the $F_{0.1}$ criterion. In their opinion this latter criterion should be adhered to owing to the unusual life history of groupers. They are long-lived, slow growing, are protogynous hermaphrodites with a greatly female-biased sex ratio, and spawn in easily exploitable aggregations. They are thus quite susceptible to overexploitation; their unusual reproductive habits would make them particularly susceptible to recruitment overfishing - something not accounted for in yield-per-recruit analyses. The decline in the related Nassau grouper, once an important component of the fishery and now considered to be commercially extinct (Bohnsack _et al._, 1986), supports their argument.

In summary, these studies indicate that in the past 10 to 15 years fishing pressure has increased to the point where the resource as a whole is fully exploited. Some, more susceptible, species are overfished, such as the Nassau grouper and red hind. The specific analyses on the grunts would indicate that the real and relative decline of these species in the landings is the result of overexploitation, and that the marked declines in other taxa (e.g., parrotfishes) similarly result from overexploitation. The large decline in landings of all species groups would argue that the analyses above may not be as conservative as they should be. It is also possible that large-scale, long-term oceanographic processes are responsible, in part, for variations in the abundance of fishes, primarily by affecting the success of larval recruitment. However, this has yet to be demonstrated and a conservative approach to management based on an interpretation of overfishing would be the more prudent course.

In the Dominican Republic, resource surveys were conducted in 1967-68 and 1977-78. Resulting catch rates for these surveys are compared in Table 12. As with the data from Puerto Rico, differences between survey methods preclude critical comparisons, but both surveys seemed to indicate that commercial abundances of fish were present at these times (FDL, 1980).

A detailed assessment was conducted in 1977-78 (FDL, 1980). In this study it was estimated that total demersal catch (including invertebrates) could be sustained at about 1.4 mt/km^2, yielding 10,740 mt from the insular platform and 6,325 mt from offshore banks. In this same study, data were presented on catch/area and number of boats/area for the principal Dominican fishing ports (FDL, 1980). These data were used to run a Gulland-Fox surplus production model (Ricker, 1975) on an areal basis, as was done in Jamaica by Munro (1977). The model predicted an MSY of 2.25 mt/km^2 with an effort of 0.788 $boats/km^2$ (Table 12). Assuming that 75% of the catch would be demersal (FDL 1980) this would yield 1.68 mt/km^2. This is probably not significantly different from the value of 1.4 mt/km^2 used in the

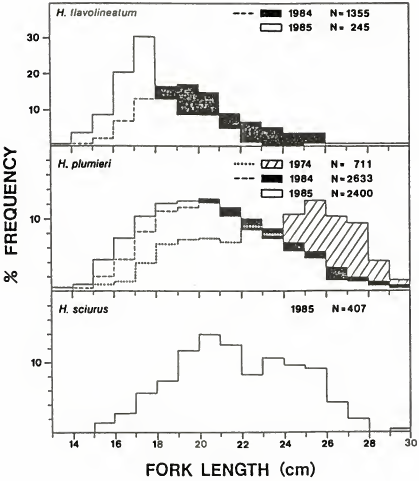

Fig. 3. Changes in Length frequency distribution of Grunts (Haemulidae) over time. (From Dennis, in press, a)

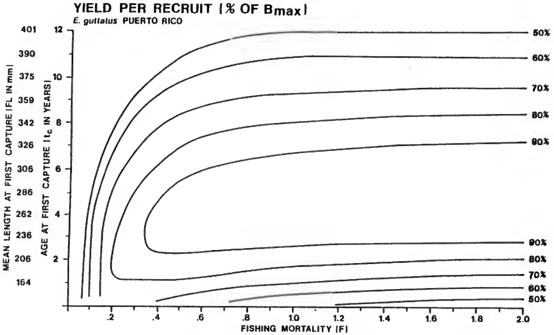

Fig. 4. Yield per recruit as percent of maximum potential yield for Red Hind (Epinephelus adscensionis) in Puerto Rico as a function of fishing mortality, age per length at first capture. (From Sadovy and Figuerola, in press)

FDL study. Present catch/area is substantially below these estimates. However, based on the status of the resource and declining landings in Puerto Rico, and on the fact that current Dominican landings/area are equal to that of Puerto Rico at its peak, the above estimates of MSY for the Dominican demersal catch may be overly optimistic.

No specific assessments have been conducted in Haiti. Cursory studies have indicated that all inshore demersal resources are substantially overfished (Brethes and Rioux, 1986; Stickney and Kohler, 1986; Ferry and Kohler, 1987). Logistical and economic constraints to deepwater fishing may have kept resources in these areas underexploited.

2.1.5 Assessment directions

Throughout the region there is a need for more and better data on the demersal catch. At one extreme is Haiti, where routine monitoring of catch still needs to be implemented. Puerto Rico's efforts are ahead of those of the Dominican Republic, but both programmes could improve their data collection efforts to provide more accurate statistics with a better breakdown by species. It is particularly recommended that analyses be attempted with current data to identify weaknesses in present data collection systems. In particular, systems for collecting length-frequency data can be made more efficient by targeting only a few species per year and rotating species between years, targeting species at only a few times during the year (e.g., one month/season), and allocating sampling taking into account seasonal variations in the catch of target species.

Standardized catch and effort sampling, and fishery independent sampling would greatly enhance the ability to monitor changes in the resource over time. This is particularly valuable in such a multispecies fishery; changes in total catch as well as in species composition could be identified. Past surveys have been conducted in both Puerto Rico and the Dominican Republic, but because of differences or vagaries in methods employed, they have not been useful as baseline studies. In Puerto Rico, the Puerto Rico Fisheries Research Laboratory has recently begun a long-term monitoring programme on the west coast using standardized line and trap fishing.

Basic biological studies on key species or species groups are still lacking. Age and growth studies and mortality estimation exist for only a handful of species. Snappers and groupers, because of their economic importance should be further studied. In addition, little information exists anywhere for important species groups such as parrotfishes and surgeonfishes. Such studies could readily be used for yield-per-recruit analysis.

Better methods need to be developed for estimating the potential productivity of shelf resources. Current estimates tend to be substantially higher than those that the fisheries have been able to achieve. The disparity between these estimates and the results of yield-per-recruit analyses illustrate the problem.

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Finally, the role of critical habitat (e.g., mangroves, seagrass beds, coral reefs) and long-term, large-scale oceanographic processes in structuring or controlling species abundance needs further attention. Critical habitats need to be identified, their status assessed and management action taken if needed. Large scale variations in oceanographic conditions have been recorded over a 30-year period off southwest Puerto Rico (Winter, pers.comm.). Such variations may affect recruitment success and subsequent stock abundance. This would greatly affect data interpretation and management policies.

2.2 Pelagic Finfishes

2.2.1 Overview of the fishery

Information on the general life history, as well as on growth rates, size frequencies, mortality rates, abundances, and other parameters needed for effective fishery management of pelagic species in Puerto Rico and Hispaniola is scarce. The information that does exist focuses on landing statistics, elementary biology, and anecdotal information.

A description of the major pelagic species for Puerto Rico and Dominican Republic is found in CFMC (1983) and FDL (1980), respectively. These species are found in the families for mackerels and tunas (Scomberidae), barracuda (Sphyraenidae), dolphinfish (Coryphaenidae), jacks (Carangidae), herrings-sardines (Clupeidae), billfish (Istiophoridae), and sharks of various families. Estimated landing data for pelagic fishes for Puerto Rico are described in Table 13 and reported landing data from the Dominican Republic are listed in Table 14.

Precise data for pelagic fishes from Haiti are nonexistent. Gulland (1971) estimated harvest of pelagic species in Haiti was 10,000 metric tons per year. Brethes and Rioux (1986), however, concluded that this eas an overestimate, with total harvests of all fishes ranging from 3,700 to 7,950 metric tons per year. They believe that migratory pelagic fishes, such as tunas, mackerels, and jacks hold the highest potential for increased harvests by weight. The pelagic fishes in Haiti are not considered to be as esteemed or marketable as "white fish", such as snappers and groupers.

The primary gear for pelagic fisheries in Puerto Rico is the troll line (CFMC, 1983). It is estimated that 100% of dolphinfish, about 90% of commercial tuna and mackerel catches, and about 75% of all barracuda are harvested with this gear. The remainder of these species are harvested by beach seines. Jacks are harvested by handlines, beach seines, gillnets, and fish traps. Table 15 lists percentages of pelagic fish harvested by gear type for the Dominican Republic. Beach seines are the primary gear used to capture migratory species in Haiti (Brethes and Rioux, 1986).

There have been pronounced fluctuations in the harvests of pelagic resources, with few common trends evident between Puerto Rico and the Dominican Republic. Examination of Tables 13 and 14 shows generally lower landings for Puerto Rico than for the

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Table 13. Estimates of annual landings (mt) of pelagic fishes in Puerto Rico.
Source: P.R. Fisheries Research Laboratory, Dept. of Natural Resources

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tuna	72.4	47.6	40.9	60.9	65.8	53.3	72.9	77.8	80.4	115.1	95.1	87.1	31.6	35.1	36.0	50.7	64.9	58.2
Dolphin	8.4	3.6	4.0	8.9	8.4	7.6	21.8	18.7	37.3	26.6	24.4	19.1	6.7	9.8	14.2	12.9	31.1	31.1
Jack	31.6	27.6	22.2	20.4	31.6	28.9	42.7	47.1	37.8	28.9	38.2	27.6	15.1	19.1	19.1	15.1	11.6	16.4
Blue Marlin	.	.	.	.	0.9	2.2	3.6	8.4	12.0	15.1	6.7	5.3	4.4	4.9	.	11.1	4.9	2.7
Barracuda	21.3	23.1	11.6	17.3	16.4	28.4	32.0	30.7	43.1	27.6	7.6	12.0	5.8	4.9	8.0	12.0	6.2	7.6
Wahoo	.	1.8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sardine	4.0	5.8	8.4	10.7	10.2	11.6	12.9	13.8	19.1	10.7	20.9	10.2	9.3	10.2	6.2	12.4	3.6	43.1
Mackerel	86.7	68.0	53.3	55.6	84.4	95.1	130.2	112.4	152.0	170.1	158.7	107.5	76.9	68.0	51.1	41.8	36.9	43.6
Tarpon	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.8	2.2
Sharks	.	.	.	.	.	.	.	.	.	.	.	.	3.6	2.7	.	5.8	13.3	13.3

Table 14. Reported landings (mt) from the Dominican Republic for costal pelagic fishes. Source: FAO Yearbooks of Fishery Statistics

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Perciformes Pelagic Pericomorphs	138	79	82	131	139	150	231	304	115	90	85	88	69	173	157
Caranx crysos (Blue Runner)	.	.	.	.	151	186	242	248	186	180	212	455	360	320	291
Caranx spp. (Crevalles jacks)	253	199	140	84	222	223	205	276	321	284	409	76	114	45	41
Trachinotis spp. (Pompanos)	136	78	94	45	75	102	102	72	83	100	65	49	137	81	74
Seriola spp. (Amberjacks)	133	99	47	25	35	48	36	45	104	108	57	76	91	165	150
Carangidae (Carangids)	133	95	65	26	38	46	26	43	66	70	23	99	42	64	58
Corypheena hippurus (Dolphinfish)	143	136	104	56	65	187	205	195	135	124	98	60	82	53	48
Megalops atlantica (Tarpon)	129	105	90	67	72	138	176	211	121	170	96	280	327	347	316
Harengule spp. (Scaled Sardines)	89	102	75	44	59	89	134	119	146	144	85	65	87	90	82
Opistonema oglinum (Atlantic Thread Herrings)	182	110	68	102	79	83	73	103	124	156	123	306	251	252	229
Clupeoids	.	100	40	393	38	61	48	56	189	108	72	104	129	80	73
Scomberomorus maculatus (Atlantic Spanish Mackerel)	295	265	253	174	317	415	479	503	384	168	1058	1267	1271	1321	1201
Scomberomorus regalis (Cero)	100	100	100	105	119	98	86	104	106	76	106	63	52	48	44
Katsuwonus pelamis (Skipjack Tuna)	213	156	78	41	64	87	59	71	80	106	68	204	600	62	56
Thunnus thynnus (N. Bluefin Tuna)	100	40	39	16	109	121	141	115	168	207	81	109	199	181	
Thunnus atlanticus (Blackfin Tuna)	124	79	90	68	78	105	125	124	144	144	106	90	123	199	181
Istiophorus platypterus (Sailfish)	.	.	.	.	.	.	.	.	22	50	49	46	18	40	36

Dominican Republic. The lack of common patterns could be due to differing migration patterns, or more likely, to a lack of standardized approach in collecting data. The lumping of different species by broad family groups in one country and specifying particular species in another country makes comparisons very difficult.

Data for tuna (Scombridae) in Puerto Rico indicate that landings were highest in 1981 at 115.1 t, while the 1987-89 period averaged 57.9 t, a 50% decline. There are no specified landings data for tuna from the Dominican Republic, although scombrids are thought to be the most important group of coastal pelagics (FDL, 1980).

Mackerel (Scomberomorus spp.) landings data for Puerto Rico for 1987 through 1989 (41.8, 36.9, 43.6 t, respectively) are the lowest for the 1971 through 1989 period. The highest recorded harvests were in 1978-1983, when landings were over 100 t, with a peak in 1981 at 170.6 t. For the Dominican Republic, landings of Atlantic Spanish mackerel (Scomberomorus maculatus) have been substantially higher than in Puerto Rico, with a peak of 1,321 t in 1987. Cero (S. regalis) landings in the Dominican Republic for 1988 were 44 t, the lowest amount harvested on record. Wahoo (Acanthocybium solanderi) landings are listed only in Puerto Rico for 1973, and totalled 1.8 t.

Barracuda (Sphyraena spp.) landings data for Puerto Rico peaked in 1980 at 43.1 t, and from 1987 through 1989 averaged less than 9 t. In the Dominican Republic, data on barracuda are not listed in FAO statistics, although FDL (1980) observed that this fish makes up 24.4% of all catches caught by fishing lines with single hooks.

In Puerto Rico landings of dolphinfish (Coryphaena hippurus) were 37.3 t in 1980, declined to 6.7 t in 1984, and have increased to 31.1 t in both 1988 and 1989. Landings in the Dominican Republic for dolphinfish reached a high level of 205 t in 1980, and declined to 48 t in 1988, a reduction of 77%.

Landing statistics for jacks (Carangidae) have been lumped together in the Puerto Rico data base, but have been somewhat separated in the Dominican Republic data. In Puerto Rico landings were highest in 1979 with 47.1 t, and averaged less than 15 t from 1987 through 1989, a 68% reduction. In the Dominican Republic harvest of Seriola spp. was greatest in 1987 at 165 t. Pompanos (Trachinotus spp.) reached a harvest of 137 t in 1986 in the Dominican Republic, with the 1987-88 period averaging 97 t.

Landing statistics for crevalle jacks (Caranx spp.) in the Dominican Republic were highest in 1984, with 409 t harvested. The three year average for 1986 through 1988 was 67 t. In 1985 landings of blue runner (Caranx crysos) in the Dominican Republic were 455 t, with the landings from 1986 through 1988 averaging over 323 t.

Although specific landings information is not available in the Puerto Rico data base for many individual species of the genus Caranx, CFMC (1983) gives generalized descriptions for several species. The bar jack (Caranx rubber) is common, but is not significantly important in the fisheries of Puerto Rico. The horse-eyed jack (Caranx latus) is frequently landed in Puerto Rico, although it is not considered to be a species with a high market demand. The yellow jack (Caranx bartholomaei) is not a major species in the fishery and is landed in small quantities. The rainbow runner (Elagatis bipinnulatus) is caught in only small quantities.

Landing data for tarpon (Megalops atlantica) from the Dominican Republic reached a peak of 347 t in 1987, with the 1986-88 landings averaging 330 t. Data from Puerto Rico are limited only to 1988 and 1989 and averaged 2 t.

Data on the landings of sardines and herrings (Clupeidae) in the Dominican Republic showed a peak harvest of 146 t in 1982 for the scaled sardines (Harengula spp.) and averaged 86 t for 1986 through 1988. The landings of Atlantic threadfin herring (Opistonema oglinum) were higher, with a maximum of 306 t recorded in 1985 and an average of 244 t for the 1986-88 period. In Puerto Rico landings of Atlantic threadfin herring in 1989 totalled 43.1 t, which is more than twice the next highest harvest of 20.9 t in 1982.

There are no landing statistics for the billfishes (Istiophoridae) other than blue marlin (Makaira nigricans) for Puerto Rico and the sailfish (Istiophorus platypterus) for the Dominican Republic. In Puerto Rico landings of blue marlin reached 15.1 t in 1981, but dropped to 2.7 t in 1989. In the Dominican Republic, data for sailfish are available for 1982 through 1988, and range from a maximum of 50 t in 1983 to a minimum of 18 t in 1986, with 36 t harvested in 1988.

In Puerto Rico data on shark landings began to be reported in 1984, and landings have increased to 13.3 t in both 1988 and 1989. There are no data on the landings for shark in the Dominican Republic.

2.2.2 Stock structure, migration, and dispersal

Very little information exists on the stock structures and identification, migratory patterns, and general dispersal of pelagic fishes for Puerto Rico and Hispaniola. The existing information is based on fishermen's observations and landing statistics, which for several species indicates a migration in an east-west direction along the edge of the shelf drop-off (CFMC, 1983).

Fishermen report that king mackerel begin to appear in catches in Puerto Rico in November and continue through April. These fish appear off the Virgin Islands a month before they appear in Puerto Rico, and they appear off eastern Puerto Rico several weeks before being harvested off western Puerto Rico (CFMC, 1983). Fishermen have been known to follow the migrating fish, which occur both in schools and as individuals.

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A year-round king mackerel population of solitary fish is also found on the reefs of the shelf, and individuals are generally larger than the average size of migrating fish (CFMC, 1983). Cero mackerel appear to be caught more often around Puerto Rico in winter (Erdman, 1978).

The little tunny (Euthynnus alletteratus) is a very common scombrid in the Caribbean and is highly desired in both commercial and recreational fisheries (CFMC, 1983). Little tunny is a schooling species that disperses at certain periods. In Puerto Rico little tunny are caught throughout the year, although there is an apparent east-west migration.

The blackfin tuna (Thunnus atlanticus) is a coastal pelagic species confined to the warm temperate and tropical western Atlantic, and is thought to be one of the more abundant tunas in the Caribbean (CFMC, 1983). It ranges from New England to Brazil and is found throughout the Caribbean. Seasonal concentrations occur near the Northern Lesser Antilles to the east coast of Puerto Rico. A directed fishery for the blackfin tuna is found on the northwest tip of Puerto Rico. The blackfin tuna is usually found in shelf areas not less than 200 m deep. This species feeds near the surface in large schools and is known to occur in schools of skipjack tuna (Katsuwonus pelamis). The blackfin tuna follows an east to west route along the edge of the shelf during migrations from the Virgin Islands to Puerto Rico. No other information on stock structures and dispersal patterns for other tunas is known for Puerto Rico or Hispaniola.

Barracuda (Sphyraena spp.) is an important food and game fish in many areas of the Dominican Republic (FDL, 1980) and Puerto Rico (CFMC, 1983). These fishes have sedentary characteristics and may establish a territory on a reef. Individual fish also travel the edge of the shelf (de Sylva, 1970).

The dolphinfish (Coryphaena hippurus) has an oceanic distribution and can sometimes be found near shore (CFMC, 1983). Fishermen have observed that this species becomes common in Puerto Rican waters in November and are caught in large numbers until May, with the largest schools occurring in April. The migration pattern is from east to west, with dolphinfish being harvested in the Virgin Islands a month before they appear in Puerto Rico. Although single fish and much smaller schools are reported on a year-round basis, these fishes are not believed to be part of a local population, but rather are moving with warm currents. Oxenford and Hunt (1986) suggest that two circuits exist for northern and southern stocks for this species, with the boundary between these groups occurring between Puerto Rico and the Virgin Islands.

No large scale routine migrations are believed to exist of the greater amberjack (Seriola dumerili) in Puerto Rico and year-round landings are believed to be from a resident population, although movement within the region however is thought to be extensive (CFMC, 1983). These fishes are usually found on reefs or at deep offshore holes in small schools, but may also be found

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as solitary individuals. Smaller fish of less than 2.7 kg are caught in waters less than 10 m deep.

The blue runner (*Caranx crysos*) forms large schools over both the shelf and inshore waters (CFMC, 1983).

Small aggregations of the horse-eyed jack (*Caranx latus*) are often seen over inshore reefs, and large adults form small offshore schools (CFMC, 1983). The species is euryhaline and has been found in fresh-water canals and coastal streams.

The bar jack (*Caranx rubber*) usually occurs in small aggregations near reefs and moves from one reef area to another (CFMC, 1983). Juvenile bar jack are found in estuaries and other inshore waters. Young mature fish are believed to move to the outer shelf, where spawning is thought to occur.

Yellow jack (*Caranx bartholomaei*) appears to be more of a bottom fish than the bar jack. The yellow jack is found over outer reefs and has been caught by inshore gillnets in Bramedero Bay, Puerto Rico (CFMC, 1983).

Adult and young rainbow runners (*Elagatis bipinnulatus*) are seen on the outer shelf, near offshore islands, and banks (CFMC, 1983). These fishes aggregate around floating debris, artificial structures or drifting vessels. Although the rainbow runner is generally found in small schools, at certain locations and times of the year large schools form at the Navidad and Silver Banks.

Blue marlin (*Makaira nigricans*) in Puerto Rico are present throughout the year with peak harvests from August through September. Smallest harvests occur in December (CFMC, 1981).

No information is available on the stock structures, migrations, or dispersal for tarpon, herrings, or sharks in Puerto Rico and Hispaniola.

2.2.3 Basic population biology

Little is known about specific aspects of the population biology for most the pelagic species in the waters of Puerto Rico and Hispaniola, although information of varying degrees is available for many of these species in other areas of the Atlantic Ocean and, in some cases, for the Caribbean.

Very little is known about the population dynamics of the cero mackerel (*Scomberomorus regalis*), the Atlantic Spanish mackerel (*S. maculatus*), or the king mackerel (*S. cavalla*). A 77.5 mm fork length cero mackerel weighing 5 kg was reportedly speared in Puerto Rico in 1962, and this species is thought to spawn throughout the year with an increase in spring and summer (Erdman, 1978). A year-round king mackerel population is found on the reefs of the shelf (CFMC, 1983), it comprises solitary fish larger than the average size of migratating fish. No fecundity studies have been made on any mackerel in Puerto Rico or Hispaniola, although Erdman (1976) indicates that a pattern of protracted spawning with greater activity in summer occurs around Puerto Rico.

Little tunny (Euthynnus alletteratus) were found to have ripe ovaries and testes from March through June in Puerto Rico (CFMC, 1983).

Little information is available on spawning patterns for blackfin tuna (Thunnus atlanticus). Ripe adults were found in April-May and September-October, and Erdman (1976) concluded that this species has a bimodal spawning pattern in Puerto Rico.

Shark species are believed to be major predators of blackfin tuna. Blackfin tuna juveniles (250 mm) were found to be the majority of blue marlin stomach contents during September (Erdman, 1976).

Specific information on life history of barracuda (Sphyraena spp.) is lacking for Puerto Rico and Hispaniola, although some adults have been noted to contain ripe gonads in winter (CFMC, 1983), and individual fish of at least 1.8 m in length are common on the south coast of Puerto Rico.

Dolphin (Coryphaena hippurus) are sexually dimorphic, although there is no apparent sexual difference in weight up to 950 mm fork length (CFMC, 1983). At greater lengths males are heavier than females. In the Caribbean area most adult female dolphin had subripe ovaries throughout the year with a probable peak in February (Erdman, 1976).

Although Erdman (1976) reported that in Puerto Rico the chief species found in dolphin stomachs was the juvenile filefish (Cantherines pullus), CFMC (1983) concluded that dolphins are non-selective feeders.

No studies have been performed to determine the life history parameters for tarpon, billfish, herrings, or sharks in Puerto Rico and Hispaniola.

2.2.4 Assessment studies

Few detailed assessment studies have been preformed on migratory pelagic fishes of Puerto Rico and Hispaniola. The Draft Fishery Management Plan for Coastal Migratory Pelagics for the Caribbean Fishery Management Council (CFMC, 1983) calculated MSY by surplus production methods for coastal pelagics in the US Caribbean Exclusive Economic Zone (EEZ), which incorporates Puerto Rico and the US Virgin Islands.

MSY was calculated for both commercial and recreational fisheries for dolphinfish, jacks, barracuda, and mackerel and for all species combined within the FMP (Table 16). Erdman (1978) observed that pelagic harvest rates could only be economically efficient if fishermen were actively trolling in conjunction with setting and retrieving fish traps. If such a conclusion is valid, then the total number of motor boats in the fishery could be used as a measure of fishing effort in the pelagic fishery. Other attempts to quantify fishing effort (number of fishermen, number of hooks, etc.) were not thought to give accurate results.

Table 15. Percentage capture by gear for selected pelagic fishes in the Dominican Republic. Modified from FDL (1980)

Species	Gear Type	
	Trolling	Trammel Net
Mackerel	36.8	
Dolphinfish	35.3	
Barracuda	24.4	
Sharks		82.3
Thread fin herring		5.2
Other (non-pelagic)	3.4	12.5

Table 16. Maximum Sustainable Yield (MSY) estimates for coastal migratory pelagic species listed in the Draft Fishery Management Plan for Coastal Migratory Pelagics for the Caribbean Fishery Management Council. Modified from CFMC (1983)

Species Categories	MSY ('000 of Pounds)
a) Individual Schafer Model	
Dolphin	*
Jacks	152
Barracuda	267
Mackerel	1,429
b) All species combined	
Schafer Model	1,231
Schafer Model (1971-1980)	1,444
Fox Model	1,334
Primary Productivity MSY Estimate	1,775
Average	1,446

* MSY cannot be calculated for dolphinfish, as slope in model is negative. This suggests that MSY could be substantially higher than listed harvest levels

Severe data limitations hampered precise estimations of MSY. Little information on the recreational catch was available, although this sector was thought to be a major component of the fishery. Four different methods were used to generate estimates of MSY: a Schaefer model using years 1969 through 1980; a second Schaefer model using years 1971 through 1980 only; a Fox model; and MSY based on primary productivity estimates. The second Schaefer model attempted to use 1969-70 as a standard for comparisons from 1971 through 1981. The primary productivity model was thought to give general rather than exact estimates. There was no information available on the mortality, growth, or recruitment rates needed to formulate yield-per-recruit models.

As no model was thought to be robust enough to give a precise estimate, the four results of the four methods were pooled and averaged, and indicated a MSY of 1,446,000 pounds, or 643 t, per year.

Catch-per-unit-effort (CPUE) of Puerto Rico's commercial pelagic fishes is described in Table 17, and shows a range of 158 kg/boat to 247 kg/boat.

2.2.5 Assessment directions

Many of the same comments in section 2.1.5 on assessment directions for demersal fisheries apply also to pelagic fishes. One of the most obvious needs in formulating effective management decisions for pelagic fisheries is better data. This includes precise landings data, catch-per-unit-effort data, age-growth relationships, length-frequency data, etc.

Available data collection efforts for pelagic species must follow a comparable format to avoid combinations of families groups and species groups, which makes detailed analysis impossible. Furthermore, the data bases must expand the scope of species listed and include detailed information on swordfish, sharks, billfish, and wahoo.

It is important for individual regional fisheries agencies to understand that trying to identify and manage local stocks of oceanic pelagic fishes (tuna and billfishes) would not be efficient, as these species range through the Atlantic Ocean and occur regionally for short periods. Although data would be required on landings, migratory patterns, catch rates, etc., to give a better description of the oceanic pelagic fishery within the Greater Antilles region, better focus should be placed on the coastal pelagic fishes with identifiable stocks, such as carangids, sardines and herrings, king mackerel, etc.

Given the migratory distribution of pelagic resources, both within the region and in the surrounding Atlantic Ocean, it is important to establish workable pan-Caribbean approaches to stock assessment and management policy. Standardization of data collection approaches is critical for successful long-term stability in these fisheries (see Section 3.2 on shared stock resources).

Table 17. Catch per-unit-of-effort in the Puerto Rico Commercial Fishery (Pounds per boat). Modified from CFMC (1983)

Year	Dolphin	Jacks	Barracuda	Mackerel
1971	65.5	192.0	102.5	666.1
1972	38.8	144.2	97.7	395.9
1973	15.2	117.8	98.9	290.7
1974	15.7	86.7	45.2	207.9
1975	31.5	71.5	61.2	196.2
1976	29.0	101.4	54.9	283.5
1977	24.2	94.3	90.4	310.4
1978	51.9	112.4	78.7	323.7
1979	42.4	84.2	69.7	256.4
1980	66.7	122.1	79.4	275.6

Table 18. Estimated landings of queen conch, *Strombus gigas*, in Puerto Rico (total and by coast) and the Dominican Republic. Values are in metric tons. Data for the Dominican Republic come from published FAO reports and include an unspecified, but small percentage of other molluscs. Data for Puerto Rico are from the Fisheries Research Laboratory, P.R. Dept. Natural Resources

	Dominican Republic	Puerto Rico				
Year	Total	North	South	East	West	Total
1977	133	1.36	30.45	12.73	69.55	114.09
1978	292	0.45	52.27	46.36	62.73	161.82
1979	412	4.68	45.06	18.14	103.58	196.01
1980	706	5.37	36.06	34.99	135.84	212.25
1981	1,291	5.25	44.75	21.05	165.52	236.57
1982	1,169	3.85	34.34	44.31	183.01	265.51
1983	1,240	5.34	51.61	35.83	172.32	265.11
1984	1,504	6.12	74.21	34.98	198.08	313.40
1985	1,798	8.31	27.88	94.66	133.39	264.24
1986	1,583	2.53	14.07	18.49	77.60	112.69
1987	577	0.55	10.08	9.97	48.34	68.93
1988	525	0.59	13.26	33.48	61.19	108.51
1989	•	0.28	10.66	24.80	37.22	72.96

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There is also a profound need to establish better understanding of occurrences of ciguatera in coastal migratory pelagic fishes, by fish species and by seasonal locations of sickness due to consumption of affected fishes (see Section 4). This effort would also include identifying marketing structures of harvested fish likely to be contaminated, the role of test kits in identifying contaminated fish flesh, and determining easy methods to identify those species likely to be contaminated.

2.3 Queen Conch (Strombus gigas)

2.3.1 Overview of the fishery.

The queen conch is one of the most important fishery species in Puerto Rico and the Dominican Republic. The species is also fished in Haiti, but limited shelf area reduces its potential; nevertheless conch is important as an export commodity (Brethes and Rioux, 1986). In Puerto Rico, conch is fished almost exclusively from small boats by divers using scuba. Typical depth ranges are from 10 to 35 m, but most fishing occurs from 18 to 27 m. In areas of calm seas and high density conch is lifted to the boat for shucking. However, in many areas the meat is removed from the shell *in situ*. In the Dominican Republic and Haiti, free diving, scuba diving, and diving with hooka (air pumped from the surface) are all used to harvest conch. Conch are routinely taken in the Dominican Republic to depths of 45-55 m. In Haiti conch harvest generally occurs at depths of 20 m or less (Brethes and Rioux, 1986).

Little information is available on the conch fishery in the Dominican Republic except for reported landings; no data are available from Haiti. In Puerto Rico extensive studies have been made of the fishery, particularly off the southwest coast. The west coast is the most important area for the fishery, but the east and south coasts also contribute significantly. In the Dominican Republic, conch fishing is largely concentrated on the south coast, historically centred around the island of Beata (FDL, 1980).

Table 18 shows reported landings of conch for the Dominican Republic and Puerto Rico. Both fisheries show similar trends. Landings increased dramatically in the late 1970s and early 1980s, then dropped, equally as dramatic. The rise and decline in Puerto Rico do not perfectly coincide with that of the Dominican Republic. Appeldoorn (1992) attributed the rise in Puerto Rican landings initially to an increase in demand and price for conch meat that led to the widespread use of scuba and the harvesting of previously underexploited areas. The last few years of increasing catch were attributed to the recruitment into the fishery of the dominant 1980 year-class, which supported the fishery for four years. Catch rates in recent years have been variable, showing no real trend; recorded catch-per-unit- effort in 1988 and 1989 was about 41 kg per trip. The Puerto Rican conch resource is felt to be overfished (Appeldoorn, 1987; 1992, in press, a); given the parallel trends in the Dominican fishery, this probably holds for the Dominican resource as well.

2.3.2 Stock structure, migration, dispersal

Little is known about the stock structure of conch in Puerto Rico and Hispaniola. Electrophoretic studies elsewhere (Mitton et al., 1989) have shown that genetic exchange through larval dispersal can occur over large distances. Appeldoorn (unpublished data) has found conch larvae in the central Caribbean Sea, thus illustrating the potential for intra-regional dispersal. Given the above, it is unlikely that discrete populations occur within the region. However, given patterns of oceanic flow and a planktonic stage of approximately 3-4 weeks, the possibility of discrete populations cannot be ruled out.

Conch are known to make two types of migrations. The first is seasonal, with conch moving offshore in the winter and inshore in the summer (Hesse, 1979; Appeldoorn, 1985; Coulston et al., 1987), and this has been observed in Puerto Rico. The second is an ontogenetic migration from inshore to offshore with age (e.g., Stoner et al., 1988). In neither of these migrations do the distances travelled appear to be large. The maximum recorded distance travelled by an adult conch in Puerto Rico was 9 km over a six-month period in an area where extensive sand-algal plains exist and allow for such movement.

2.3.3 Basic population biology

The basic biology of conch has been reviewed elsewhere (Randall, 1964; Alcolado, 1976; Appeldoorn et al., 1987; Berg and Olsen, 1989). Reviewed here are aspects particular to the resource of Puerto Rico and Hispaniola. All of these are related to studies conducted off the southwest coast of Puerto Rico.

Conch grow in shell length until the onset of sexual maturity, at which time they form their characteristic flared shell-lip that subsequently thickens over time. Appeldoorn (1988a, 1990, in press, a) has modelled growth in shell length, lip thickness, and weight. Von Bertalanffy growth parameters have been calculated for shell growth in length for juveniles (using both age-increment and length-frequency data), and in lip thickness for adults. These are given in Table 19. Table 20 gives length-weight conversions for both wet tissue weight and wet meat weight. The former is defined as the whole animal without the shell; the latter is the animal with the visceral mass removed but otherwise intact. Simple equations cannot be given for predicting adult weight. This is primarily determined by size at maturation, and secondly by subsequent adult growth as indicated by growth in lip thickness (see Appeldoorn, 1988a). However, analysis seems to indicate that the rate of growth in weight drops markedly after sexual maturity, although significant growth still occurs. The population studied by Appeldoorn matured at a mean shell length of 24 cm. Average growth in weight for adults of this size has been modelled (Appeldoorn, 1988a) and combined with growth in weight for juveniles to obtain single equations (based on the Gompertz function) for growth in weight over all ages (Appeldoorn, in press, a). The resulting equations are:

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Table 19. Von Bertalanffy growth parameters for juvenile (shell length) and adult (lip thickness) *Strombus gigas* off La Parguera, southwest Puerto Rico. GI = growth increment data, AL = age length data, L is in millimetres, time is in years. Source: Appeldoorn (1988a, 1990)

Growth Model	Method	L_{inf}	K	t_o
Shell Length	GI	460	0.25	0.24
Shell Length	AL	340	0.44	0.46
Shell Lip-thickness	GI	55	0.37	--

Table 20. Equations converting shell length to wet weight for *Strombus gigas* off La Parguera, southwest Puerto Rico. Source: Appeldoorn (1988a)

Log^{10} (Meat Weight) = $-2.535 + 3.486\ \text{Log}^{10}$ (Length)

Log^{10} (Tissue Weight) = $-2.286 + 3.459\ \text{Log}^{10}$ (Length)

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$$\text{Meat Weight} = 4.394 \times 10^{-7} e^{20.12 (1 - e^{-1.275 t})}$$

$$\text{Tissue Weight} = 1.263 \times 10^{-5} e^{17.44 (1 - e^{-1.126 t})}$$

where weight is in grams and age (t) is in years. The equations above, particularly those incorporating adult weight growth, will not be generally applicable. Growth in conchs is very variable and seems to be affected by habitat conditions. Figure 5 illustrates the variability in mean shell length of adults from six sites on the west, south and east coasts of Puerto Rico. Average size varied by more than 2 cm between sites. In addition, it can be seen that females average slightly larger shell lengths than males. This difference varied among sites, ranging from 2 to 24 mm.

Estimates of instantaneous fishing (F) and natural (M) mortality have been determined from mark-recapture studies and length-frequency analysis. For juveniles and adults combined, M was estimated at 1.05 yr^{-1} (Appeldoorn, 1987). For adults only a value of 0.52 yr^{-1} was obtained (Appeldoorn, 1988a). The difference between these two reflects age-related differences in mortality rate (Appeldoorn, 1988b), with the higher estimate resulting from the inclusion of juveniles. A mark-recapture estimate of fishing mortality was obtained for the period between 1983 and 1985 of F = 1.14 (Appeldoorn, 1987). An identical estimate was obtained by comparing estimates of catch/ha to exploitable biomass/ha for the year 1985 (Appeldoorn, 1992).

The age at which conch start to mature was estimated at 3.2 years, with first reproduction occurring at an age of 3.6 to 4 years Appeldoorn (1988a). Spawning off Puerto Rico has been observed from late April to mid-November (pers.obs.), although some inter-annual variability is to be expected. There are no estimates of spawning rate of conch within the region. Potential rates of 7-8 egg masses per spawning season (Davis et al., 1984) and 400,000 eggs per egg mass (Weil and Laughlin, 1984) have been reported elsewhere.

Inter-annual variations in recruitment have been observed, with the dominant 1980 year-class in Puerto Rico being well documented. However, the significance of this variability in the long-term has not been assessed. Evidence from elsewhere (Stoner et al., 1988; Berg, pers.comm.) suggests that adult conch can be long-lived and recruitment of large year-classes may be rare events. In Puerto Rico, the smallest conch taken by the fishery are about 15 cm in length; full recruitment occurs at about 19 cm.

2.3.4 Assessment studies

Several studies have attempted to assess in some manner the status and potential of the Puerto Rican conch resource. The resource is felt to be over-exploited. Evidence for this comes from several sources. First is the sharp decline in conch landings observed in the mid-1980s. Second is the low relative

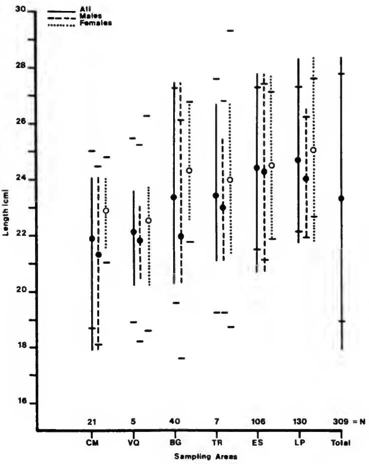

Fig. 5. Variations in shell length (cm) among 6 sites within Puerto Rico. Lines Represent ranges,points are means, and bars are 2 standard deviations on either side of the mean. Sample size = N. CM = Chaade Muertos. VQ = Vieques. BG = Buoy 6, West Coast. TR = Tourmaline Reef. ES = El Sical, West Coast. LP = La Parguera

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density of conch observed relative to other areas. In a 1985-86 survey off the southwest coast, an average of 8.11 conch/ha were found, at a time when landings were declining. These values were an order of magnitude less than those observed in the Bahamas, and two orders of magnitude less than those observed in unfished areas in Los Roques, Venezuela (Appeldoorn, 1992). Third is the high level of fishing mortality relative to natural mortality, indicating that harvest was exceeding production.

Appeldoorn (1992) attempted to estimate maximum sustainable yield (MSY) using the Gulland-Fox surplus production model (Ricker, 1975) applied to 1970s data from the west coast of Puerto Rico. The model predicted an MSY of 0.57 kg/ha. Total yield for Puerto Rico was estimated at 227 m (500,000 lb), twice the level of current landings. However, it was not possible to determine to what degree fishing pressure would have to be reduced to achieve this yield. This level of MSY also assumes that all areas of the shelf are equally exploited, which because of depths and sea conditions, is not the case.

For the Dominican Republic, no quantitative assessments are available, but the resources are thought to be well overfished. Former productive shallow areas have been fished out and are no longer productive. The extreme depths and conditions under which conch divers now operate suggest the last remaining portion of the resource is being harvested. Peak landings of MSY (obtained from interpolating production per unit of area from Puerto Rico to the Dominican shelf).

2.3.5 Assessment directions

Present understanding of the conch resource in Puerto Rico is based on landing trends and some detailed biological and assessment studies. Only landings data are available for the Dominican fishery, and no information is available from Haiti. Data collection efforts could be improved in all areas. Current growth and mortality models need to be employed in yield per recruit analysis. However, such analysis will be heuristic to some degree, due to the fact that growth and final adult size are highly variable and under strong local habitat control. Also, because of this variability it is difficult to develop uniform size-based management measures; however, harvest limits based on the attainment of maturity are possible. Very little information exists on the reproductive output of conch. This would be needed to estimate spawning potential ratio (see e.g., Section 2.4.4), which is currently a basis for management within the US EEZ.

As with fishes, critical habitats (e.g., nursery areas) need to be identified and assessed.

2.4 Spiny Lobster (Panulirus argus)

2.4.1 Overview of the fishery

The spiny lobster is an important resource throughout the region. Lobsters are harvested in traps and by diving. All fishing is done from small boats. Traps are either standard fish traps or specific lobster traps; these are fished for periods of several days to a week before hauling. Diving is with scuba in Puerto Rico, and by free diving or with scuba or hooka in the Dominican Republic. Little is known on this fishery in Haiti, but it is reported to be the most important Haitian fishery because exports are an important source of foreign revenue (Nweihed, 1982; Brethes and Rioux, 1986).

Table 21 and Figure 6 show the trends in lobster landings from the three countries, although estimates from Haiti are not based on a direct survey of the fishery. Data from Hispaniola show a variable but increasing trend in lobster landings. No assessment has been made of the Dominican fishery. All inshore Haitian resources are thought to be overfished (Stickney and Kohler, 1986; Ferry and Kohler, 1987). Landings from Puerto Rico have fluctuated greatly. These fluctuations reflect variations in effort as well as possible long-term variations in recruitment. Landings have steadily declined during the 1980s. About 15% of Puerto Rico's catch comes from the east coast, 45% from the south coast, and 35% from the west coast (Matos and Sadovy, 1990). The majority of lobsters are taken in standard fish traps; in recent years divers have accounted for roughly 30-45% of the catch. No effort data specific to spiny lobster are available, but effort is thought to be increasing, particularly through an increase in the number of scuba divers. The resource is thought presently to be suffering from growth overfishing (CFMC, 1990). Current regulations in Puerto Rico ban retention of berried females and individuals less than 89 mm (3.5 inches).

2.4.2 Stock structure, migration, dispersal

Little is known of the stock structure of spiny lobster in general, and no specific studies have been conducted in either Puerto Rico or Hispaniola. Spiny lobster have an extended planktonic stage, lasting 6-12 months (Lewis, 1951; Ingle et al., 1963; Buesa, 1970), and are thus capable of dispersing over wide areas. Using electrophoretic techniques, Menzies et al. (1978) and Menzies (1981) found some genetic differences between widely scattered areas and felt stocks may be broad, encompassing areas of several hundred miles. The above would argue that there would be little stock discrimination between or within Puerto Rico and Hispaniola, although this cannot be ruled out entirely.

In areas of extensive shelf (e.g., Florida) tagging studies have shown lobsters to be capable of long distance migration. One study suggests juveniles may disperse hundreds of miles from nursery habitats to adult habitats (Davis and Dodrill, 1980), and tagged adults in Florida have been observed to move as far as 100 miles in 100 days (Smith, 1954). However, this dispersal capability is thought to have little effect on the local stock structure. Hispaniola and Puerto Rico lie on different insular platforms. Within Hispaniola, the insular shelf is extremely narrow at the boarders between Haiti and the Dominican Republic, and little relative exchange would be expected.

Table 21. Estimated landings of spiny lobster, _Panulirus argus_. Landings are in metric tons. Data for Haiti and Dominican Republic are from published FAO reports. For Puerto Rico, data are from CMFC (1990)

Year	Puerto Rico	Dominican Republic	Haiti
1951	212.2	.	.
1964	68.2	.	.
1969	160.9	.	.
1970	189.5	.	.
1971	117.3	.	100
1972	107.7	.	100
1973	113.6	300	100
1974	110.9	100	100
1975	141.4	157	100
1976	174.5	106	100
1977	191.4	86	100
1978	205.0	139	100
1979	232.7	339	100
1980	215.5	166	100
1981	218.6	229	100
1982	163.2	270	100
1983	133.7	546	250
1984	128.8	165	250
1985	120.2	784	250
1986	99.6	429	250
1987	71.9	823	250
1988	65.3	748	250
1989	84.7	.	250

Table 22. Mean carapace length of spiny lobster, _Panulirus argus_, in the catch from Puerto Rico. Source: CMFC (1990)

Year	Carapace Length (in)	(mm)	Number Sampled
1951	4.4	113.0	.
1956	4.0	101.6	1276
1968	3.8	95.3	223
1978	3.7	93.5	9232
1980	3.7	92.8	129
1981	3.8	95.3	5574
1983	3.7	94.4	211
1986	3.6	92.5	568
1987	3.8	95.6	387
1989	3.5	90.1	392

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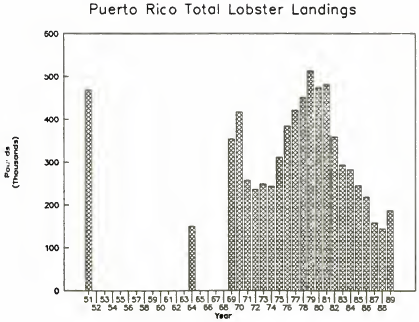

Fig. 6. Total spiny lobster (Panulirus argus) from Puerto Rico (From CFMC, 1990)

2.4.3 Basic population biology

General reviews of the population biology of spiny lobsters are given by Herrnkind et al. (1975), Lyons et al. (1981), Gregory et al. (1982) and Appeldoorn et al. (1987). A few published studies exist for Puerto Rico.

No specific estimates of growth parameters and mortality exist for spiny lobsters from either Puerto Rico or Hispaniola. Although length-frequency data have been collected in Puerto Rico for several years, these have not been suitable for estimating growth or mortality (CFMC, 1990). Limited tagging and length-frequency data from juveniles show a clear seasonal growth pattern with maximum growth occurring in August-October and minimum growth in February-March (Boardman, 1981).

In Puerto Rico, Feliciano (1958) found an even sex ratio, and the smallest mature females were 86.4 mm (3.4 inches) in carapace length (CL). A more recent survey found mature females of less than 75 mm CL (CFMC, 1990). Females with spermatophores and eggs are found in all months; however, a seasonal peak in mating and spawning occurs from April to June (Feliciano, 1958). Estimates of fecundity by Feliciano (1958) ranged from 434,000 to 1,691,000 eggs, and the size-fecundity relationship did not appear different from those reported elsewhere (e.g., Mota Alves and Bezerra, 1968).

Seasonal recruitment of pueruli stage lobsters off southwest Puerto Rico was monitored by Monterrosa (1986). Recruitment occurred year-round, with a maximum in late summer-early fall and a secondary peak in the spring. Recruitment patterns also showed evidence of lunar periodicity. Trapping studies done in the same region (Boardman, 1981) show recruitment of juveniles into trap catches starting at about 10 mm CL. Recruitment showed a seasonal pulse in late summer-early fall. Although the Puerto Rican fishery has a minimum size limit of 89 mm CL, lobsters start recruiting to the fishery in significant numbers at 70 mm CL.

2.4.4 Assessment studies

No assessments have been reported for either the Dominican Republic or Haiti. Data for Puerto Rico were recently reviewed and the fishery assessed (CFMC, 1990). This study concluded that the Puerto Rican resource was overfished, and that this has contributed to the decline in landings in the 1980s. Data, given in Table 22, show a steady decline in the mean size of the catch. Currently, 40% of the catch is below the legal size limit. However, comparison of length-frequency distributions between Puerto Rico and the heavily-fished Florida Keys indicated less exploitation in Puerto Rico. The decline in size at first maturity observed in Puerto Rico from 1957 to 1989 is characteristic of a population under intense fishing pressure. The study calculated a Spawning Potential Ratio (SPR), defined as the ratio of eggs produced between a fished and unfished population. Estimates from the unfished Florida Dry Tortugas were used for the comparison (Gregory et al., 1982). The calculated SPR was 55.9%. A 20% SPR is generally considered a minimum value for maintaining stock health in the absence of empirical evidence to the contrary (Goodyear, 1989). Thus, the Puerto Rican resource does not appear to be in danger of collapse.

2.4.5 Assessment directions

Current assessment capabilities derive from the ability to monitor changes in the catch in terms of landings and size structure. The latter can also be related to legal size limits. As with other resources, better monitoring of spiny lobster is possible and desirable, including both landings and catch/effort data. Length measurements, to be useful for length frequency analysis, must be on the scale of 1 mm or less. Such a small length-class interval requires large sample sizes.

Detailed growth and mortality estimates for lobster in the region are not currently available. These would be of great assistance in detailing stock status and potential. In the particular case of the US Caribbean they are also necessary for more properly estimating the spawning potential ratio, which is the current basis for defining recruitment overfishing.

Critical habitats need to be identified and assessed.

3. SPECIAL PROBLEMS

3.1 Multispecies Fisheries

Throughout the region, almost all fishes caught are utilized. All gears, be they hook-and-line, traps or nets exploit a variety of species. In addition, there is a large overlap in the species exploited by each gear. Thus, the fisheries of the region, in particular that for demersal fishes, can be considered multispecies fisheries. As a consequence, there is limited flexibility for managing individual species, except for conch, lobster and larger pelagics. Management necessarily will have to be aimed at optimizing yield from the entire shelf, and not on a species-specific basis. In doing this, some species will be overexploited, others underexploited. A perfect example of the former in Puerto Rico is the demise of the Nassau grouper as a commercially important species. However, management must consider economic yield as well as biological yield. Species such as grouper, with life histories making them particularly vulnerable to overexploitation, are on the one hand more likely to decline in an intensively fished area, but on the other hand they are one of the more commercially valuable species. Thus, achieving maximum biological yield may result in a reduction in economic yield. Management of shelf resources in the US Caribbean EEZ is generally aimed at optimizing overall yield, but this is subject to the constraint that no species is reduced to the point where the local stock may become extinct. At present, the Nassau grouper stock may be close to this point.

Differences between gears and how they are fished may lead to reductions in stock potential. Many shelf species make an ontogenetic migration from inshore grassbeds and mangroves to coral reefs progressively further from shore and at greater

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depth. Throughout the region, hook and line fishing tends to occur in deeper water, trap fishing occurs at slightly shallower depths to inshore, and net fishing closer to shore. Thus, fish may be exposed to a variety of gears of different selective properties over their life histories. For example, beach seines are often used to catch small inshore fishes. However, they also catch large numbers of the juveniles of larger fishes, contributing to growth overfishing of these species.

Another potential conflict exists between the offshore commercial longline fleet and the recreational sports fishery. The commercial fleet is primarily interested in swordfish, but as by-catch tuna, billfishes, and sharks are taken. The recreational fishery primarily targets blue marlin, but also takes tuna, other billfishes, dolpinfish, wahoo and other pelagics. As each fishery continues to expand the by-catch will increase. In the US EEZ recreational fishermen have successfully had sale of blue and white marlin prohibited.

3.2 Shared Resources

Individual accounts of stock structure have been reviewed under the sections detailing each resource. Presented here are some general considerations. The first of these concerns the potential for shared stocks due to genetic exchange through larval dispersal (Type IIb: Types refer to Caddy, 1987). Most reef fishes have larval stages of several weeks duration. The same is true for conch. Given the mean current flow in the region it is certainly possible that there exists but one stock in the region, with sources upstream contributing to areas downstream. However, there is some circumstantial evidence that stock structures may be more complex. Perhaps the best evidence of this was the pattern of dispersal of the sea urchin, Diadema, die-off in the early 1980s (Lessios et al., 1984). The disease reached Puerto Rico from the Lesser Antilles to the east and Hispaniola from the west. Semi-permanent eddy systems within the region create an eastward flowing current along the south coast of Hispaniola (Figure 2). This current does not seem to penetrate across the Mona Passage to Puerto Rico. Water along Puerto Rico's southern coast generally flows either west, well south of Hispaniola, or through the Mona Passage and potentially along the north coast of Hispaniola. Thus it is possible that the southern coasts of the islands harbour separate stocks.

Under the upstream-downstream scenario management, should be on a regional basis. However, most demersal resources are sedentary after larval settlement. As such, maximizing yield-per-recruit, which does not account for effects of fishing on reproductive potential, could easily be managed by individual states. If separate stocks occur, management could be at a more local level.

The second consideration is the possibility of migration of adults and juveniles across national boundaries (Types IIa, III and IVa). Puerto Rico shares its shelf with the US and British Virgin Islands. It is possible that some demersal species readily cross jurisdictional boundaries (Type IIa). It is probable that coastal pelagic species do (Type III). The same would apply to Haiti and the Dominican Republic, although in the case of demersal species the adjoining shelves are particularly narrow, thus limiting exchange. It is also possible that the larger coastal pelagics migrate between Puerto Rico and Hispaniola (Type IVa). Management of the these species, particularly the migrating coastal pelagics, should be on a regional basis. Species such as dolphinfish, with separate southern and northern stocks migrating through the area point to the need for pan-Caribbean management mechanisms. At present, for management purposes the resources of the Puerto Rico - Virgin Islands platform are considered to constitute single stocks. Between Puerto Rico and the US Virgin Islands these resources are jointly managed, and an active liaison is maintained with the British Virgin Islands. However, no cooperation exists between Puerto Rico, the Dominican Republic, or Haiti.

Oceanic pelagics (Type IVb), such as bluefin tuna, swordfish, etc., are only transitory within any country's EEZ. Management of these species cannot be done even at the regional level. However, there exist several international forums for the management of these species (e.g., ICCAT, IATTC).

4. CIGUATERA

The southern coasts of Puerto Rico and the Dominican Republic have been identified as areas where ciguatera poisoning is prevalent, while for the north coasts it has not been reported (de Sylva and Higman 1980, Olsen et al., 1984). No information is available from Haiti. The principal species of dinoflagellates implicated with ciguatera in this region are Ostreopsis lenticularis and Gambierdiscus toxicus; the abundance of these species has also been shown to vary seasonally (Ballantine et al., 1988).

The principal demersal species in which ciguatera has been reported are large individuals of the shallow-water snappers (Lutjanus apodus, L. jocu, L. mahogoni) and the Spanish hogfish (Bodianus rufus) (Olsen et al., 1984).

Pelagic fishes are widely known to carry ciguatera, but in varying amounts of hazard for certain fishes and during certain periods of the year (CFMC, 1983).

Cero (Scomberomorus regalis) are not considered as dangerous a source of ciguatera as barracuda (Sphyraena spp.), amberjack (Seriola spp.), bar jack (Caranx rubber), or horse eye jack (Caranx latus) (Sylvester, Dammann and Dewey, 1977).

The king mackerel (Scomberomorus cavalla) is not considered a highly toxic species, although rare reports of toxic individuals exist (CFMC, 1983). There appears to be a higher incidence of fish poisoning from fish which are members of year-round resident populations than fish from migrating populations. This species is also subject to scomberomorus poisoning if poorly handled.

Barracuda (Sphyraena spp.) larger than 1 or 2 kg are almost never consumed in Puerto Rico (CFMC, 1983). Studies conducted on barracuda in southwest Puerto Rico have shown the incidence of ciguatera to vary seasonally, with two cycles of high incidence per year (Tosteson *et al.*, 1988). Peak seasons were from January to May, and from August to November, with up to 65% of fish being toxic. Low periods occurred in June-July, and again in December. The high incidence of ciguatera in large barracuda is perhaps explained by its characteristic of feeding on one reef.

After the great barracuda, the greater amberjack (*Seriola dumerili*) is the fish most feared for ciguatera poisoning. The high incidence of muscular parasites in this species is also a deterrent to its consumption (CFMC, 1983).

Almaco jacks (*Seriola rivoliana*) are thought to cause ciguatera poisoning in many areas in the Caribbean, including Puerto Rico. Local knowledge suggests that this species is highly toxic prior to spawning (CFMC, 1983).

Smaller bar jacks (*Caranx rubber*) are not considered to be highly poisonous. Larger fish have been found to be toxic in Puerto Rico (Halstead, 1967).

The horse-eye jack (*Caranx latus*) is known to cause ciguatera poisoning and is avoided, especially in the south coast of Puerto Rico (CFMC, 1983).

Yellow jacks (*Caranx bartholomaei*) are considered less of a threat than many of the other jack species and larger individuals are avoided (Dammann, 1969).

Small blue runners (*Caranx crysos*) of about 1 kg are highly mobile and are not considered to be as toxic as larger individuals, but are not eaten in areas of high ciguatera incidence (CFMC, 1983).

The little tunny (*Euthynnus alletteratus*) is generally considered to be safe to consume, although some cases of ciguatera have been noted (CFMC, 1983).

Wahoo (*Acanthocybium solanderi*) and blackfin tuna (*Thunnus atlanticus*) are not usually considered dangerous and are widely consumed (CFMC, 1983). The low toxicity in these species may result from offshore feeding. These fishes generally move from one region to another and do not feed exclusively on one reef, which is thought to limit the accumulation of ciguatoxins in their tissues.

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PART 3

JAMAICA

by

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ABSTRACT

A review of the marine fishery resources of Jamaica is presented. It includes a description of the oceanography and physical characteristics of the island's coastline, its off-shore banks, and surrounding seas. Detailed summaries of the biology and status of stocks of the most important resources, including oceanic and coastal pelagic fishes, queen conch and spiny lobster.

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1. DESCRIPTION OF THE AREA

1.1 Overview

Jamaica in 1988 had a population of approximately 2.43 million and Gross Domestic Product of US$2,858 million. The agricultural GDP in 1987 was US$174 million with fisheries accounting for approximately 1% of this amount. In 1987 the unemployment rate in Jamaica stood at 21% of the labour force (PIOJ, 1988).

Jamaica is located in the Greater Antilles, in the Caribbean Sea, approximately 145 km south of Cuba and 161 km west of Haiti (Fig.1). The island is 236 km long, between 35 and 82 km wide, with a total land area of 10,940 km^2. and a coastline of approximately 885 km.

The topography consists of an interior backbone of mountain ranges running almost the length of the island from roughly east to west, surrounded by flat coastal plains. The Blue Mountains in the east have the highest peak at 2,256 m. The interior of the central and western two-thirds of the island is dominated by a limestone plateaux, the majority of which lies between 350-610 m (NRCD, 1987).

The coastal plain is less than 3.2 km wide along most of the north coast. In some areas the plain widens to form broad embayments, the most extensive of which are located at the eastern, western and south-central sections of the island. Swamp land occurs in some areas of the coastal plain notably in the western section of the Island (NRCD, 1987).

The irregular coastline is punctuated by numerous coastal features such as harbours, bays, beaches, estuaries, mangrove swamps, rocky shores, cays, coral reefs and lagoons. These natural features provide a resource base that contributes significantly to the economic well-being of the country, chiefly through tourism.

Jamaica has a tropical maritime climate which is modified by northeast trade winds and land-sea breezes. Temperature is fairly uniform in the coastal areas. The average temperature is 27^0 C, ranging from a low of 23^0 C, in the winter (January and February) to 28^0 C in the summer (June-August). Humidity is usually above 60% and is generally highest in the morning (85%), falling slightly by mid afternoon. Rainfall in Jamaica is marked by monthly, annual, and spatial variability. The average annual rainfall for the entire island is 195.8 cm and greatest rainfall occurs from October to November with a secondary peak in May.

1.2 Oceanographic Features

The Island lies within the path of north-easterly trade winds and wind speeds exceeding 15 m/sec with associated choppy seas are common. A season of relative calm usually occurs between October and February each year (Munro, 1983). There is

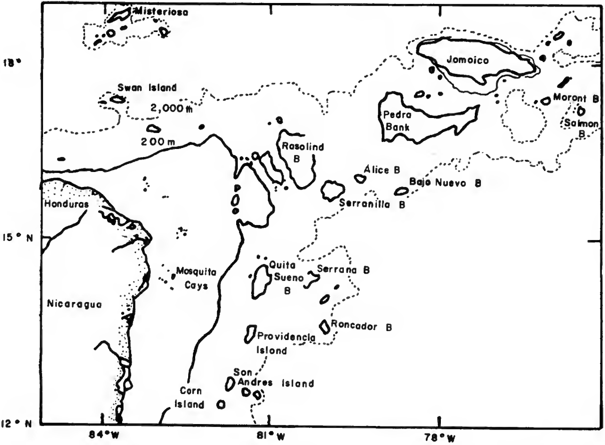

Fig. 1. Map of Southwestern Caribbean Sea showing location of Jamaican and various offshore banks. Depth contour is 200 m isobath. (Adapted from Munro and Thompson, 1983)

a hurricane season in the Caribbean from July to October each year during which unstable weather systems, including violent storms, occur.

The branch of the North Equatorial current which flows westwards and enters the south-eastern Caribbean Basin is the dominant surface current system affecting Jamaica. It exits the Caribbean Sea via the Yucatan Channel and then passes between Florida and the Bahamas as the Florida current before rejoining the eastern branch of the North Equatorial current to become the Gulf Stream, and eventually the upper portion of the North Atlantic Gyre (Lyons, 1980; Apel, 1987). The presence of east flowing surface and sub-surface counter currents and gyres on both sides of the main current has been reported by Emilson (in Munro, 1983).

Munro (1983) reported that tidal effect on the Jamaican Coast is slight, the range varying between 20 cm and 36 cm. Tidal currents on Pedro Bank are reported to be sometimes sufficient to stop or reverse the flow of the prevailing westerly Caribbean current.

The annual temperature range of the surface waters south of Jamaica down to a depth of about 75 m is reported to be between 26.5°C and 29.5°C (Munro, 1983). Goodbody and Munro (1971) reported fairly constant salinity of 35.2 to 35.8% in the waters south of Jamaica.

2. MARINE HABITAT

Jamaica has a 12 mile territorial zone around the main Island as well as around the offshore Morant and Pedro Cays. In keeping with the provisions of the International Convention on the Law of the Sea, Jamaica is presently in the process of drafting a bill for the establishment of a 200 mile Exclusive Economic Zone (EEZ), which would include the existing 12 miles territorial limit. The matter, however, is a complex one and may take some time to be successfully implemented.

2.1 Island Shelf

The Island shelf and nine proximal banks (Fig.1) have a total area of 4,170 km^2. The South Shelf is relatively wide whilst the North Shelf is very narrow and its width does not exceed 1.6 km at any point. The North Shelf is characterized by fringing coral reefs with few gaps, from Morant Point in the east to Negril in the west. The fringing reef and the sill reef are almost contiguous along the north coast. The South Shelf attains a maximum width of 24 km south of the parishes of St. Catherine and Clarendon (Fig.2). Large reefs are restricted to the eastern portion of the South Shelf, small patches of corals, gorgonians and seaweeds, interspersed with sandy patches are found in most other areas of the South Shelf. Well developed sill reefs occur along most of the edge of the South Shelf. The sill reef and drop-off are generally characterized by massive corals.

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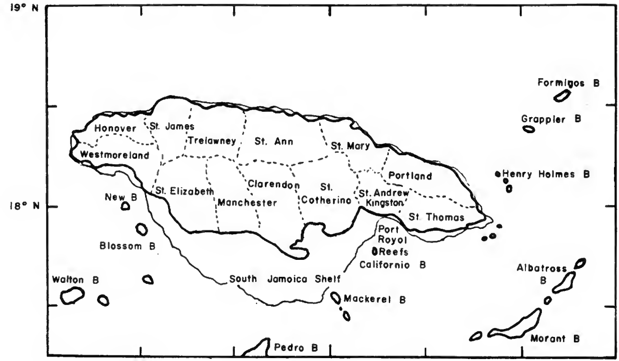

Fig. 2. Map of Jamaica showing island shelf and proximal offshore banks. 200 m depth contour shown. (Adapted from Munro and Thompson, 1983)

2.2 Offshore Banks

The Morant and Pedro Banks rise abruptly from depths exceeding 500 m to form submerged plateaux with average depths from 20 to 30 m. Pedro Bank is relatively large with a total area of 8,040 km² whilst the Morant Bank is relatively small being approximately 100 km² in area (Munro and Thompson, 1983).

The Pedro Bank may be divided into various depth zones as follows:

0 - 10 m	171 km²	(2.1%)
10 - 30 m	5917 km²	(73.7%)
30 - 50 m	1948 km²	(23.3%)

The top of the Pedro Bank is relatively flat whereas the edges are characterized by sill reefs of various sizes. The shallowest, south-eastern, southern and south-western portions of the Bank, which face into the Caribbean Current, have the best developed reefs. The middle of Pedro Bank is dominated by silt and sand with sparsely dispersed patches of sea grass, algae, and isolated coral heads. In contrast to the edge, the middle of the Bank is reported to be relatively unproductive (Munro and Thompson, 1983). Beyond the sill reefs at the edge of the Bank the depth increases abruptly sometimes by near vertical drops to more than 500 m. At the eastern section of Pedro Bank there are three small cays two of which are inhabited by fishermen. Small cays also occur on the Morant Bank, and are occupied by fishermen.

3. MARINE FISHERY RESOURCES

3.1 Organization of the Fisheries

In order to fully understand the different types of resources, their locations and rates of exploitation in the Jamaican fishery, it is first necessary to examine briefly the organization of the fishery itself.

The fishery of Jamaica is made up largely of artisanal fishermen operating from open canoe type boats powered by either outboard motors or oars. There are approximately 12,000 registered persons who fish using approximately 4,000 boats from 168 fishing beaches scattered around the Jamaican coastline. The artisanal fishery may be sub-divided into two main sectors, the inshore fishery and the offshore fishery.

3.2 The Inshore Fishery

The inshore fishery takes place in the coastal waters of the Island shelf and its nine proximal banks (Fig.1). Historically, the shelf and proximal banks have supported the bulk of fishery activities in terms of manpower and vessels. The major fishing gear used in the artisanal fishery is the Z-shaped antillean fish trap. Other common gear include gill nets, seine nets, hook-and-line, and spearguns. There is some collection of crustaceans, molluscs and algae by divers.

3.3 The Offshore Fishery

This includes fishing operations that are based on the offshore cays, as well as deep-sea fishing conducted by vessels operating independently of any land base for extended periods. There is at present a fleet of approximately 250 mechanized canoe type boats and approximately 700 fishermen based on the Morant and Pedro Cays (Fig.1). They are serviced by carrier boats in the 10-26 m size range which ply between the Cays and Kingston, transporting supplies to the fishermen and returning with fish in ice. During the 1980s there was a significant change in the fleet of carrier vessels with smaller, faster, open hull vessels replacing the larger decked boats. In addition to the Cay based operation, there are about five vessels ranging in size from 15-30 m operating on either the Pedro Bank or in extra-territorial waters. The Morant Bank supports about 120 fishermen using between 40 to 50 canoe type vessels (Anon., 1989).

The fisheries of Jamaica are based primarily on multispecies coral reef fish resources. Families of major economic importance are Lutjanidae, Serranidae, Carangidae, Mullidae, Scaridae, Haemulidae, Balistidae, Acanthuridae, Holocentridae, Chaetodontidae, Palinuridae (lobsters). Among the coastal pelagic fishes the most important families are Clupeidae, Engraulidae, Mugilidae, Scombridae, and Hemiramphidae.

3.4 Production Statistics

There is not as yet a permanent system for the collection of catch and effort statistics on an island-wide basis. The available estimates have come from Government surveys conducted on irregular basis, as well as from research projects. Limited data are also obtained from the Fisheries Division through various monitoring programmes. Available figures for landings from the inshore fishery are presented in Table 1. Catch estimates by Government sample surveys are presented in Table 2. The six surveys showed an average of 7,600 t with a standard deviation of 1,400 t. Landings from the offshore fishery are estimated to be about 2,000 t annually. Total catch from all areas of the Jamaican fisheries is estimated to be about 9,000 t.

It is important to note that prior to 1955 there was no offshore fishery and the total catch came from the inshore fishing grounds. In 1955 a boat mechanization scheme was launched by the Fisheries Division and by 1981 approximately 54% of the fishing boats in the Island were mechanized. Soon after the mechanization programme started some boats from beaches along the South Jamaican Shelf travelled to Pedro Bank to fish and returned to their home base with the catch. The sample surveys conducted before 1981 assumed that the fish landed on the South Shelf beaches were captured solely from the South Shelf. The mixing of the catch from Pedro Bank with that from the South

Table 1. Estimates of fish production from Jamaica insular shelf only from 1945 to 1981

Year	Estimated Production (Inshore only) (t)
1945-1949	5,450
1950-1954	4,990
1955	6,580
1956	7,720
1958	10,260
1959	9,900
1960	10,300
1962	10,990
1968	6,630
1970	6,260
1971	7,080
1973	7,300
1975-1978	7,300
1981	7,220

Source: Chuck (1963), Harris 1963), Nembhard (1970, Russel (1975), Munro (1974), Vidaeus (1970), Bodurtha (1975), FAO/IDB (1971), FAO/IDB (1979), Sahney (1982)

Table 2. Government fishery surveys and total production in Jamaican waters

Year	Inshore Fishery Production (t)	Total Production (t)
1962	10,990	13,245
1968	6,630	11,159
1970 (unpublished)	6,260	8,545
1971 (unpublished)	7,080	9,363
1973	7,300	10,940
1981	7,220	9,727

Source: Chuck (1963), Nembhard (1970), Russel (1975) and Sahney (1982)

Shelf means that the productivity of the South Shelf may have been overestimated.

3.5 Status of the Fisheries

Aiken and Haughton (1987) analyzed the available statistical data on the inshore fishery and found that although the total catch and the total number of boats in operation changed very little between 1968 and 1981, very significant changes in fishing effort and fishing pattern were taking place as a consequence of the process of mechanization. Between 1968 and 1981 fishing effort was estimated to have doubled whereas the catch remained at about the same level.

An examination of the process of mechanization of the fishing fleet reveals that very significant changes in both fishing effort and fishing patterns were taking place. The mechanized canoes which are replacing the unmechanized canoes are capable of carrying more fishermen, going farther offshore, spending longer periods in the fishing grounds and hauling more fish traps than the unmechanized canoes. As a consequence, they harvest more fish per unit of time.

Haughton (1988) developed a standardized measure of fishing effort which was termed "effective canoe effort". Since 1968 the catch per effective canoe has been steadily declining and by 1981 it was 59% of the catch rate in 1968 (Fig.3). A logarithmic surplus production model of the inshore fishery in Jamaica suggests that maximum yields of around 2.2 t/km^2/year are possible with a fishing intensity of between 1.0 to 1.2 mechanized canoes per km^2 of shelf (Fig.4).

3.6 Comparative Yield Levels

The available figures published by FAO (1987) indicate that for the entire Caribbean region, the average yield from shelf areas around the Caribbean islands is around 0.5-1.5 t/km^2/year. This is less than some earlier estimates, which tended not to take into account the proportion of relatively unproductive sandy bottom. In Jamaica on the other hand the average yield from the island shelf and proximal bank, computed from the Government sample surveys, was 1.7 t/km^2/year between 1968-1981.

3.7 Resource Assessment and Yields

Stock assessment studies of Jamaica's fishing grounds have been conducted by Munro (1969-1973), Cuba-Jamaica Fisheries Research Project (1977-1978), USSR-Jamaica Fisheries Research Project (1979-1980), and Hartsuijker and Nicholson (1979-1981).

The first comprehensive fish stock assessment study of the Jamaican fish resources using fish traps, hook-and-line, and direct observation technique for gathering data was conducted by a team led by J.L. Munro from 1969-1973. This study estimated the total potential harvest of fish from Jamaica to be approximately 16,000-17,000 t/year, with the Island shelf

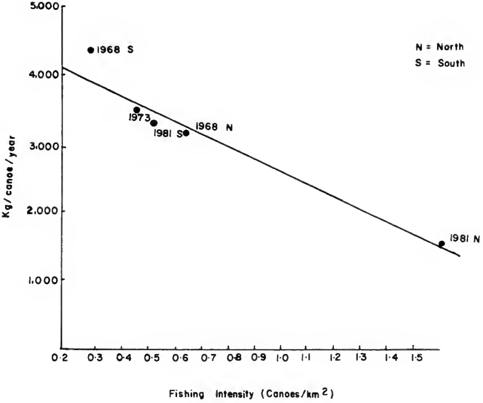

Fig. 3. Catch per effective canoe against fishing intensity (number of effective canoes) on Jamaican Shelf (from Haughton, 1986)

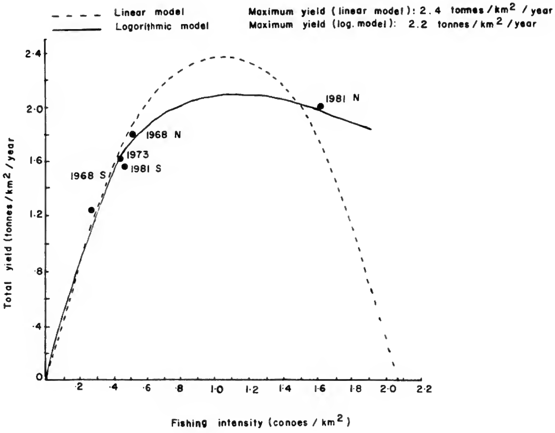

Fig. 4. Surplus yield models of the Jamaican Shelf reef fishery (from Haughton, 1988)

producing 7,300-8,500 t/year, and the Pedro Bank producing approximately 8,200 t/year.

Hartsuijker and Nicholson (1982) did a re-assessment of the fish resources on Pedro Bank using Z-shaped antillean fish traps. They estimated the total potential yield from the Pedro Bank to be 2,500 t/year and argued that the estimate of potential yield should be based on the proportion of productive reef areas and should exclude unproductive areas (e.g., open sandy grounds). Hartsuijker and Nicholson (1982) presented data which suggested that the actual reef area of Pedro Bank was only about 32% of the entire bank.

The USSR-Jamaica Fisheries Survey was conducted between June 1979 and March 1980. During that time trawl surveys on the abundance of demersal fish stocks were carried out on the South Shelf and on Pedro Bank. Additionally, two longline, four oceanographic and two ground surveys were also conducted. The estimated potential allowable catch of demersal species from the Jamaican fisheries was estimated at 15,000 t/year, with 8,100 t from the Island Shelf and 6,900 t from Pedro Bank. This survey also provided estimates of potential longline catches from Jamaica of approximately 3,500 t/year.

The Cuba-Jamaica fish stock assessment survey was conducted between 1977-1978 to determine the extent of the resources in selected zones using traps, handlines and longlines. This Project was very limited and was dominated by low catch rates. Highest catch rates from all three fishing techniques were obtained on Pedro Bank. Highest trap catch rates averaged 6.7 kg/trap/day at southwest Pedro Bank while bottom longlines gave best catch rates of 19.11 kg/hook at northwest Pedro Bank. Best catch rates from surface longlines and handline were 3.26 kg/hook and 31.25 kg/line/hr respectively also from Pedro Bank. Table 3 provides a comparison of potential yield estimates obtained by the various studies for Jamaica.

4. COASTAL PELAGIC FISHERY RESOURCES

The investigation of the resource potential of coastal pelagic species has been the objective of a three year study by the Fisheries Ecology Research Project of the University of the West Indies from 1979-1982. The results of these studies were not available up to the time of writing. It is anticipated that exploitation of underexploited pelagic resources will provide both increased landings and the possibility of some reduction in the fishing effort for the overexploited demersal trap fishery. Landings of all types of pelagic fish resources in Jamaica, according to the 1981 fisheries survey (Sahney, 1982) make up 26% of the total catch. Oceanic pelagics account for 21% of the total pelagic landings.

Gillnet and some seine net are the principal gear type used in the coastal pelagic fishery. Catches tend to be predominantly of pelagic fish (Clupeidae, Carangidae, Engraulidae, Mugilidae, Scombridae, and Hemiramphidae. The thread Herring (Opisthonema

Table 3. Summary of total potential harvests from Jamaican waters (Munro 1974, FAO/IDB, 1979)

	Potential estimated in 1974 (Munro) (t)	Estimated yield in 1978 (FAO) (t)
1. South Jamaica Shelf and adjacent banks (by traps, nets and lines)	3,400 - 4,600	
2. Northern, Eastern and Western shelves (by traps, nets and lines)	3,900	7,150 (all shelf area)
3. Pedro cays trap fishery	1,500	
4. Pedro Bank (area exploited)		
Traps	6,200	1,600 (both traps & lines)
Lines	500	
TOTAL	15,750 - 16,950	10,710

oglinum) and the Brazilian sardinella (Sardinella braziliensis) are the two most commercially important species in the coastal pelagic fishery. The unavailability of statistical, biological and ecological data on the coastal pelagic fishes in Jamaica continues to make accurate assessment of the fishery difficult. Grant (1981) and Harvey (1982) studied the coastal pelagic fishery in Jamaica but did not present any estimate of potential yield on an island-wide scale. Grant, however, estimated the potential yield of clupeidae from Kingston Harbour, which is approximately 22 km^2, to be about 166 t/year.

There has apparently been a re-direction of effort by an increasing number of fishermen towards gill net-fishing for the relatively underexploited and accessible coastal pelagic fish, due, according to Grant (1981), to the decline in catch rates of the coastal reef fishery.

5. OCEANIC PELAGIC FISHERY RESOURCES

Data on oceanic pelagic fishing in Jamaican waters are rather scarce but one of the earlier reports was given by Oswald (1963) who obtained catches of up to 90.7 kg/year using trolling lines. The 1967 FAO/UNDP Caribbean Fishery Development Survey obtained a mean trolling catch rate of 30.4 kg per fishing hour on various Jamaican banks. In the waters south and southwest of Jamaica the barracuda (Sphyraena barracuda) dominated the catches followed by tunas. Generally, catch rates were very low.

Surface longlining fishing surveys of oceanic pelagic resources were also conducted by the 1967 FAO/UNDP survey. The gear consisted of a Japanese longline comprising a 394 m main line with six-branch lines at 56 m intervals. The survey took place off the north coast of Jamaica between December 1966 and February 1967 with the longlines having between 250-516 hooks. Mean catch rates of between 0.4 to 1.7 fish per 100 hook were obtained. The fish caught included blue marlin (Makaira nigricans), white marlin (Tetrapterus albidus), and bluefin tuna (Thunnus thynnus).

The Cuba-Jamaica Fisheries Research Programme during 1977-1978 and the USSR-Jamaica Cooperative Fisheries Research Programme during 1979-1980 conducted surface longline fishing in the waters around Jamaica. Catch rates, as in the previous longline surveys were low, with sharks being the predominant species caught. The bulk of the catch was made up of dusky shark (Carcharhinus obscurus), tiger shark (Galeocerdo cuvieri), and reef shark (C. leucas). Other fishes taken were dolphin fish (Coryphaena hippurous), wahoo (Acanthocybium solandri), yellowfin tuna (T. albacares), blue marlin (Makaira nigricans), and various species of Carangidae.

Munro (1974) pointed out that no accurate assessment of the potential resources was possible for the oceanic pelagic fish species. This is because most of these species undertake extensive migrations and are known to be subject to exploitation on a regional basis. Fishing activity for these species elsewhere in the Caribbean Sea will necessarily affect Jamaican yields as the number that pass through local waters will be changed according to regional fishing effort.

Since December 1989 a fleet of about six American longline sword fishing boats in the 15-30 m size class have been operating in the waters adjacent to Jamaica's 12 mile territorial limits. Longlines of between 20-50 miles with light sticks and up to 500 hooks baited with squids were being used. The fishermen have reported average catch rates of 450 kg of swordfish (Xiphias gladius) per fishing night (Anon., 1990).

These catch rates were much better than expected based on the results of previous scientific surveys. It seems appropriate, therefore, that a re-assessment of the oceanic pelagic resources in the waters around Jamaica should be done using the modern technology available.

6. LOBSTER RESOURCES

The spiny lobster (Panulirus argus) is widely distributed in the coastal waters and the offshore banks around Jamaica. It is a high priced resource and represents an important component of the total landings of the Jamaican commercial fisheries. The largest concentration of lobsters are found on the Pedro Bank which provides 60% of the landings (Fig.1). The stocks, particularly on the northern coast have, however, been depleted as a result of overfishing (Aiken, 1983; Aiken and Haughton, 1987). Total landings of P. argus in Jamaica are estimated to have increased from about 260 t in 1981 (Sahney, 1983) to about

550 t in 1986 (Fisheries Division, 1987). Prior to 1982 the Jamaican lobster fishery was primarily an artisanal fishery. Lobsters were taken along with a large variety of fish in the Z-shaped antillean fish traps. Skin divers using spearguns also made a small contribution to the catch. Since 1982, however, there has been a marked increase in the exploitation of the lobster resource. In 1982 a new industrial fishery targeting the lobster on the Pedro Bank was started. This fishery comprised about 5 lobster boats in the 25-30 m size class, using Florida type wooden lobster traps.

In addition to the industrial fishery a small number of artisanal fishermen have, since 1982, exclusively fished lobster using either lobster traps or free or scuba divers. The divers are sometimes equipped with scuba equipment and spearguns. Most of the artisanal fishermen, however continue to catch lobster as by-catch in the Z-shaped antillean fish traps.

The fishing effort for lobster has therefore been increasing rapidly since the early 1980s, with an increase in the number of fishermen, the number of traps, and the number and size of fishing vessels.

Studies conducted by Munro (1983), Aiken (1977), 1983) and Haughton (1988) confirmed a significant reduction in the mean and modal size of the lobster population in Jamaica. The mean lengths of males and females obtained by Munro (1983) in the 1969-1973 study were 118.2 mm CL and 102.3 mm CL respectively, compared with 100.5 mm CL and 92.5 mm CL reported by Haughton (1988) from the 1986-1987 study. This reduction is probably due to the increase in fishing pressure that has occurred over the last decade. The mean and modal size of the lobster population are still well above the minimum legal size of 76 mm CL, and slightly greater than the mean size at maturity of 84-90 mm CL (Aiken, 1983).

The sex ratio of P. argus in Jamaica is close to one (Munro, 1983; Haughton, 1988). The length/weight relationships for male and female P. argus are not significantly different. The value of the exponent (b) obtained by Munro (1983) was 2.74 for both sexes combined.

Munro (1983a) calculated growth parameters from the results of tagging experiments in Belize, and obtained a K value of 0.21 per year and Loo of 190 mm CL for males and females combined. The Gulf of Mexico and South Atlantic Fishery Management Councils (1982) reported K = 0.25 as the best estimate for male and female combined. Haughton (1988) obtained growth parameters of K = 0.26 and Loo = 205 mm CL for male and female P. argus in Jamaica.

Munro (1983) used catch curve analysis to estimate natural mortality (M) for P. argus from the unexploited parts of Pedro Bank during the 1969-1973 study (Z = M in unexploited stocks). The values obtained were M = 0.4 for males and M = 0.6 for females. Haughton (1988) obtained estimates of total mortality (Z) of 2.19 and 2.88 for males and females respectively.

Haughton (1988) reported that the mean exploitation rate (E) on the fully recruited size classes in 1986 were E = 0.77 for females and E = 0.59 for males. These values are greater than the accepted optimum exploitation rate of 0.5 or less (Pauly, 1984), and suggested that the population on the Pedro Bank is overexploited.

Serious consideration should, therefore, be given to reducing fishing effort in the lobster fishery. It is important to emphasize, that rational management and exploitation of Jamaica's lobster stocks have wider regional implications. The major source of recruits for the lobster population at Pedro Bank are not likely to be the product of local spawning stocks. As a consequence of the prolongued planktonic larval life some of the larvae produced by the local spawning stock are likely to be swept up current to fisheries such as those along the costs of Florida and the Gulf of Mexico. A Regional Pan-Caribbean management policy is, therefore, basic to the development of an optimal strategy for the efficient management and conservation of P. argus in Jamaica.

In summary, therefore, it can be stated that the lobster populations in Jamaica have changed considerably since Munro (1983) study. Fishing effort has increased significantly over recent years and the present level of fishing mortality appears to be greater than the optimum recommended for the fishery. From a biological perspective, fishing mortality should be reduced to minimise the risk of overexploitation. Finally, further studies are needed to clarify the uncertainty regarding the source of recruits, the settlement of the puerului, and the period of larval life, to refine the population parameters reported above, and obtain selection parameters and population size.

7. CONCH RESOURCES

There are no published reports on these resources from Jamaican waters except that by Aiken (1979) which summarized the known activities at that time. Small-scale coastal collection by skin-divers in certain areas still predominates. The major species taken is Strombus gigas (the Queen Conch), with lesser numbers of the smaller and less abundant species, such as S. pugilus and S. gallus also being taken.

Some attempts have been made since 1987 to undertake large-scale collection by skin-divers on at least the two largest offshore banks, the Pedro and Morant Banks to the south of the island. Statistics are scanty and may be sketchy but seem to indicate that substantially large quantities are taken by decked-vessel-based skin-divers who thoroughly search open-sea grass covered areas of those banks down to about 25 m depth and sometimes deeper. One estimate is of 22,320 kg taken by two vessels in three weeks. Large mounds of recently landed shells on the cays of both Pedro and Morant Banks attest to recent activity in conch fishing. Reports suggest that most of the conch taken on the offshore banks are sold directly to foreign-based fishing vessels (in the 25 m size range) which visit those areas specifically to purchase conch and sometimes lobster. It is believed that most of the conch sold goes to the United States market in the fresh-frozen condition.

8. SUMMARY

The artisanal fishery of Jamaica produced an average of 9,000 t from all areas according to the most recently available figures. The coral reef fishery resources are thought to be overexploited with various indicators such as declining catch per unit effort, changes towards lower-valued herbivorous species, smaller mean sizes and increasing conflict between fishermen, all becoming more commonplace.

A number of resource surveys between 1970 and 1980 suggested potential yields significantly higher than current catches. However, these are now thought to be overestimates which did not allow for the relatively large areas of relatively unproductive shelf. Pelagic resource surveys have been unpromising but since the end of 1989 apparently successful sword fishing by U.S. vessels, has been carried out in international waters close to Jamaica's territorial limits suggesting that a re-assessment of pelagic resources is in order. Spiny lobster resources have produced landings up from approximately 260 t in 1981 to roughly 550 t in 1986. Most of this increase has come from Pedro Bank. There has been a trend towards the development of an industrial fishery for lobsters using larger (20-30 m) decked vessels operating with large numbers of Florida lobster traps. Conch resources on Pedro Bank have since 1989, experienced increased levels of fishing effort and it appeared from reports that good catches were obtained in certain regions of that bank. Catches are harvested by hand by skin divers operating from a few decked vessels up to 25-30 m in length, who would collect conch mainly for export.

The Jamaican fishery is in need of proper management and efforts are being made in this respect to have an integrated programme of management with proper enforcement.

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CUBA

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ABSTRACT

A review of the marine fishery resources in the Cuban archipelago is presented. It includes a description of the oceanography and physical characteristics of the Cuban coastline and surrounding seas and of the main marine ecological ecosystems: estuarine, seagrass - coral reef and oceanic. It covers a brief account of the historical development of Cuban fisheries and their management and detailed summaries of the present knowledge on the biology and status of stocks of the most important species, including the spiny lobster, shrimps, tuna, coastal pelagics and reef fish.

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1. INTRODUCTION

Though this work commissioned by FAO is an updated and abridged version of "Los Recursos Pesqueros del Archipiélago Cubano" (Baisre y Páez(1981), it contains an appreciable amount of new information and a thorough revision of Cuban fishery statistics for 1935 to 1990.

With the increase in fishing effort in the last ten years, the Cuban fishery sector can be said to have reached full development (Baisre, 1985a), so the previously estimated maximum annual global catch of 80 000 t remains valid. Efforts to improve fisheries management have therefore become increasingly important in recent years. However, sound scientific solutions to the complex problems of evaluation and management of multi-specific demersal species are as yet incomplete, and considerable progress still needs to be made in the evaluation of highly migratory species such as tuna and similar species.

2. PHYSICAL AND BIOLOGICAL CHARACTERISTICS

2.1 General

The Cuban Archipelago, with a total area of 110 922 km^2 (Anon., 1978), lies in the western tropical Atlantic. This is sometimes referred to as the American Mediterranean (Sverdrup et al, 1946) which includes the Caribbean Sea itself, the Gulf of Mexico and the adjacent Atlantic Ocean waters off the Bahamas and the Greater Antilles. The whole area, which is also known as the Greater Caribbean, has an average depth of some 2 200 m and a total surface area of 4.3 million km^2 (FAO, 1980).

The most notable oceanographic feature of the region is a continuous current (the Antilles Current), which flows from East to West under the influence of trade winds, passes through the Yucatán Channel, gains in intensity and follows along off the coast of Florida and the United States (Gulf Stream).

Atlantic waters flow constantly into the Caribbean through the different passages between the islands of the Greater and Lesser Antilles and the South American Coast (Rossov, 1967; Febres-Ortega and Herrera, 1978; Nelepo, 1978). Most of this water is discharged through the Yucatán Strait, though some returns to the Atlantic through the passages of the Greater Antilles. This water exchange amounts to some 35 million m^3/sec (Nelepo et al., 1978).

The marine hydroclimate of Cuba is predominantly humid and tropical, and is largely influenced by the trade winds that blow during most of the year. The dry season lasts from November to April and rains are particularly heavy during the summer and autumn months (May to November). The major tropical depressions (cyclones and hurricanes) produce additional and sometimes extremely heavy rainfall, and greatly influence the hydrography and marine life of the region (Baisre and Páez, 1981).

Though the temperatures are predominantly tropical, sporadic continental cold fronts in winter from the northern polar regions

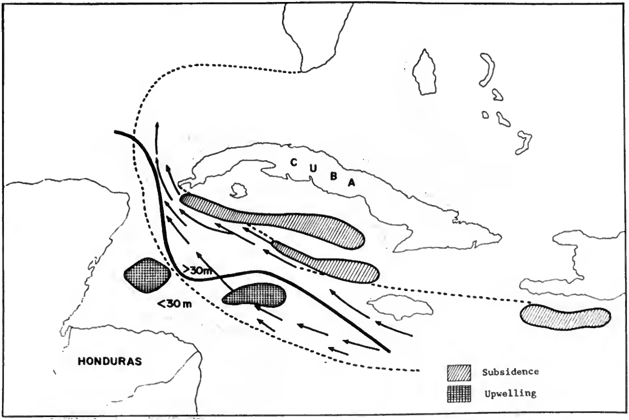

Fig. 1. Map of the Caribbean region with some outstanding oceanographic characteristics. Water flows are indicated by arrows. Dotted lines indicate areas where the current is strongest. (From Baisre, 1985b)

can produce water temperature changes too abrupt for certain organisms. These changes are important for fisheries as they influence the accessibility of certain commercial species (breeding runs or homing).

The marine climate and the shallowness of the shelf in many areas greatly influence oceanographic conditions. The coastal waters generally have warm and uniform temperatures from the surface to the bottom with seasonal and local variations determined by changes in air temperature.

Salinity is stable except in areas with sediment deposit and river outflow or semi-closed areas with high evaporation and restricted water exchange. Oxygen levels are very close to, and sometimes even above, saturation. Nutrient concentrations are limited.

2.2 Oceanic Waters

Studies on oceanic circulation show how the velocity of Atlantic waters (Northern Equatorial and Guayana Currents) flowing into the Caribbean is intensified by the trade winds, forming the Antilles or Caribbean Current (Gordon, 1967). This current divides the Caribbean into two basins, a northern one, south of the Greater Antilles, with large anti-cyclone formations producing water troughs or subsidence, and a southern one where cyclonic and anti-cyclonic gyres alternate off the continent (Rossov and Santana, 1955; Nelepo et al, 1978). Caribbean oceanic waters also have a marked thermal stratification which prevents vertical mixing and is partially responsible for the low fertility (Corredor, 1978; Nelepo et al, 1978).

As a result, there are upwellings off the Guajira peninsular in Colombia, in the Campeche Bank and off western Florida (Corredor, op. cit.). These produce areas with primary productions as high as 1.0 gC/m^2/day off the coast of Venezuela, whilst productivity falls to below 50gC/m^2/year in the central part of the Caribbean Sea and in the Gulf of Mexico (FAO, 1972). The areas, south of Cuba and other islands of the Greater Antilles are stratified trough areas with limited nutrient availability (Margalef, 1971; Lluis, 1972 and 1977) and very low primary productivity (Fig. 1). These observations are supported by additional data from a study on the primary production and phytoplankton of these areas.

Both Kondratieva and Sosa (1967) and Kabanova and López (1973), using the radiocarbon method, found very low primary production values (between 0.1 and 20 mg C/m^3/day) particularly in the southern part of Cuba. The phytoplankton in these waters also reflects existing hydrographic conditions. López and Vinogradova (1972) report that plankton in the southern part of Cuba is characterized by few diatoms and an abundant cyanophyceous "algae", mainly Oscillatoria (Trichodesmium) thiebautti, which can account for approximately 70% of the phytoplankton profile. Nannoplanktonic organisms are also very scarce.

In the Old Bahama Channel, the phytoplankton is typical of slightly more productive waters and, according to López and Vinagradova (op. cit.), is characterized by intensive diatom development and a lower cyanophyceous algae content, this being the only area around Cuba with a predominance of diatoms and dinoflagellates.

Regardless of the above results, the absence of constant and significant upwelling in oceanic waters off Cuba explains the absence of sizeable pelagic concentrations around the archipelago.

Oceanic fisheries only account for slightly more than 5% of the total EEZ catch and are restricted to certain regions around the Cuban archipelago of which a relatively narrow strip, only occasionally extending beyond 10 n.m. from the shelf-edge, is fished.

2.3 The Shelf

According to Pavlidis and Avello (1975) the Cuban shelf is a special kind referred to in publications as an "island shelf" characterized by the following factors: 1) shallow depth; 2) the presence of shallow reefs, keys and banks at the edge of the shelf; 3) the presence of narrow shallow zones which are not real shelves; 4) the abruptness of the island shelf. These characteristics help to distinguish the nine areas or stretches of coast that generally make up the Cuban shoreline (Marrero, 1950), and to determine their specific characteristics. As a general rule, areas with a broad shelf have a gentler slope than those with a very narrow shelf.

On this basis four main fishing areas can be identified (northwestern, northeastern, and southeastern platforms and the Gulf of Batabano), all with a relatively broad and shallow shelf and each separated from the other by areas with virtually no shelf (Fig. 2). These areas, with a total area of approximately 54 000 km^2, account for virtually 100% of the neritic fisheries, as fishing in bays (Cabañas, Cienfuegos, Nuevitas, Nipe, etc.) or other coastal zones is extremely limited.

From 1976 to 1980 island shelf catches represented 96.4% of the total catch in the EEZ.

3. TYPE AND DISTRIBUTION OF MAIN FISH STOCK

Fishery production in the Cuban Economic Zone (EEZ), as in any other fishing area, depends on the rapidity of solar energy storage in the form of organic carbon through photosynthesis (primary production) and on the efficiency with which this energy is transferred through the ecosystem to the commercial species (secondary production) and finally to humans. The greater the diversification in the transfer of this energy (the greater the number of links in the chain), the smaller the quantity available to humans.

Using as the basic classification criteria the channels for energy absorption in the ecosystem and the rapidity of the

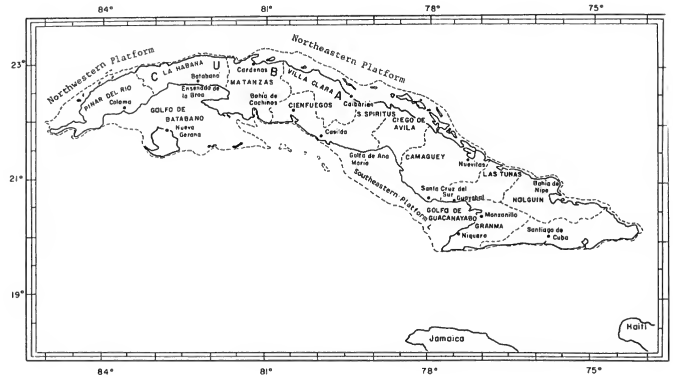

Fig. 2. Map of Cuba showing the four main fising zones and main localities mentioned in the text

internal recycling processes, Baisre (1985 b), has indicated that Cuban fisheries are based on three ecological subsystems that are inextricably linked but qualitatively different: the coastal estuarine complex, the seagrass and coral reef complex and the oceanic water complex (Fig. 3). These three complexes can also be identified with slight variations throughout the Caribbean region.

3.1 Coastal Estuarine Species

The coastal estuarine complex is limited to a few parts of the Cuban shelf, certain bays in areas generally surrounded by mangroves, and coastal lagoons with river basin drainage systems which, with the help of the predominant currents, facilitate sediment retention. This complex characteristically has very fine sediment, greater depth and higher primary production than other areas, as well as simpler food chains with species of short life-cycles, and fast-growth species. The most representative species are the white shrimp (Penaeus schmitti) and the southern pink shrimp (P. notialis) though there are also: mullets (Mugilidae), mujarra (Gerridae), turkey wing (Arca zebra) and pelagics such as the Atlantic thread herring (Opisthonema oglinum) and the King, Spanish and painted mackerel (Scomberomorus spp.).

3.2 Seagrass and Coral Reef Species

The seagrass and coral reef ecosystem occupies the greatest island shelf area. It develops in all areas where shelf depth or river outflow do not limit the development of seagrass or impede coral growth. These areas are generally very transparent and shallow, with a complex spatial organization due to the shelf topography which produces a random order of reef patches, sandbanks, keys and islands, all of different sizes and complexity. Primary production in this complex is low; the predominant sediments are organogenic sands; the food chains are highly complex and the species have slow growth, long life-cycles and elaborate behaviour patterns. The most representative species is the spiny lobster (Panulirus argus), but there are also sizeable demersal groups such as snappers (Lutjanus), groupers (Serranidae), grunts (Haemulon), other fish species (numerous families) and the queen conch (Strombus gigas). The few pelagics are limited to pilchards (Harengula), jacks (Caranx) and related species, and neritic sharks.

3.3 Oceanic Species

The oceanic ecosystem surrounds the whole country beyond the shelf, though for the purposes of this report the area under consideration is limited to a 5 n.m. range which is that generally fished. This complex has low nutrient availability, low primary production and no upwelling.

All the species are high market-value pelagics. The bonito (Katsuwonus pelamis) and the albacore (Thunnus atlanticus) are the smallest and can feed off the limited zooplankton and micronekton available in these waters. The remainder are only occasional migrants such as marlins and billfish (Istiophoridae),

COASTAL ESTUARINE ▨			SEAGRASS - REEF ▧			OCEAN WATERS ░		
Area 8,500 km^2 Fish Yield 1.9 t/km^2/yr			Area 45,000 km^2 Fish yield 0.8 t/km^2/yr			Area 13,800 km^2 Fish yield 0.21 t/km^2/yr		
Species	% catch in National waters		Species	% catch in National waters		Species	% catch in National waters	
White shrimp	Penaeus schmitti	14.0	Lobster	Panulirus argus	23.9	Bonito	Katsuwonus pelamis	5.4
Pink shrimp	Penaeus notialis		Lane snapper	Lutjanus synagris	5.4	Albacore	Thunnus atlanticus	
Oyster	Crassostrea rhizophorae	5.3	Mutton snapper	Lutjanus analis	2.3	Ocean shark		0.9
Atl. thread herring	Opisthonema oglinum	4.7	Grey snapper	Lutjanus griseus	2.0	Billfish	Istiophoridae, Xiphidae	0.9
Mullet	Mugilidae	1.4	Yellowtail snapper	Ocyurus chrysurus	1.5			
Span. & King mackerel	Scomberomorus sp.	1.1	Grunts	Pomadasydae	5.0	Total		7.2
Mojarras	Gerridae	1.0	Nassau grouper	Epinephelus striatus	1.7			
Clam	Arca zebra	1.0	Sharks		4.4			
Stone crab	Mennips mercenaria	0.5	Sardines	Harengula sp.	3.0			
Total			Jack mackerel	Caranx sp.	0.8			
			Total		50.0			

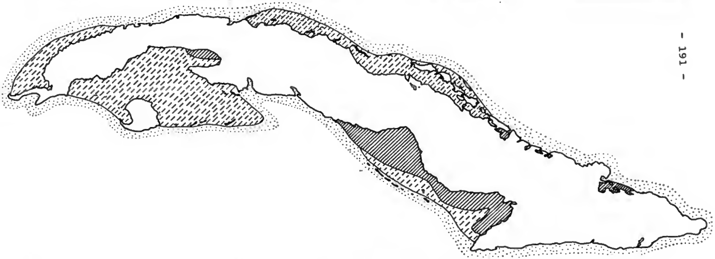

Fig. 3. Map of Cuba showing the distribution of the main commercial species and ecosystems/fishing zones

swordfish (Xipias gladius) and various ocean shark species. Sometimes large yellowfin tuna are also found (Thunnus albacares).

Figure 4 details the distribution of the main commercial species and their dependence on environmental factors. It also lists the main fishing gear used.

4. MAIN FISHERIES

4.1 Historical Development

According to Baisre (1985 and 1987a, b and c), the establishment in the 1930s of the first spiny lobster processing plants, the take-off of the sponge and shark industry, the initiation of exports and the introduction of fishery statistical records identify this period as the beginning of commercial fisheries. Until 1950, the fishing industry developed very slowly and operated below capacity (Fig. 5), with total catches amounting to some 10 000 t/year, over 30% from the Gulf of Mexico.

Despite the serious socio-economic crisis of the 1950s, specific events in the fishery sector spurred investment, increasing the total catch to some 20 000 t in the years before the revolutionary triumph in January 1959 (period of growth). Among the most relevant features of this period were the development of the bonito fisheries, the installation of the first canning plants, the discovery of new shrimp shoals in 1953 and the increase in lobster production from 1955. Though growth began in 1953, investment only increased after 1959 (industrial plants, boat construction, cold stores, ice plants, etc.), which led to a sizeable increase in catch levels until 1976. This increase was also accompanied by organizational changes (the Government takeover of virtually the whole sector from 1968), technical changes (the introduction and modernization of fishing gear), and the utilization for the first time - from 1969 - of the bycatch.

Unfortunately, most of the fishery regulations that could control the increase in fishing effort were suppressed from 1968 leading to overfishing of major stocks such as mullet (1971), oyster (1974), lane snapper (1976), shrimp (1977) and conch (1978). This period lasted from 1976 to 1981 with fluctuating and falling catches, dropping to below 60 000 T in 1981. Considering that the changes in fishery administration policy (best illustrated by the spiny lobster fishery regulations adopted in 1978) became generalized from 1981, this year marks the beginning of the Cuban fishery management period. Among the most significant aspects of the period were: the re-introduction and introduction of fishing regulations, a drastic reduction in boat construction, the fishing of underexploited stock such as crab (Callinectes), clams (Arca zebra) and some fish (Clupeidae, Gerridae) and an improved use of the bycatch from the shrimp fishery. Landings are currently levelling off at around 75 000 t/year.

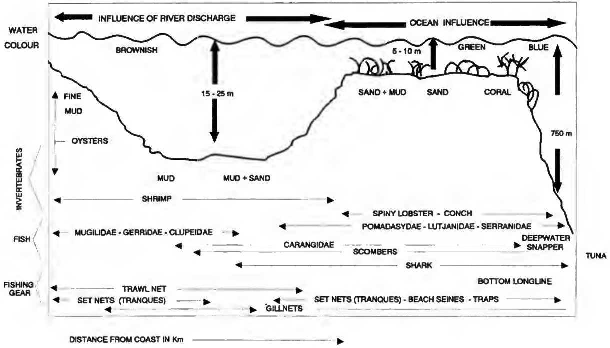

Fig. 4. Cuban fisheries: diagram

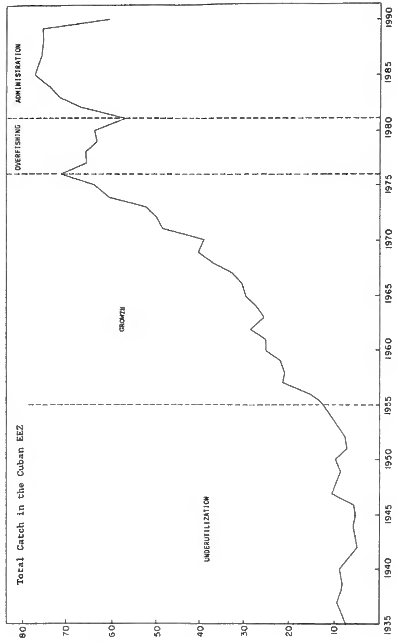

Fig. 5. Historical trend of catches in Cuba's EEZ

The significant fall in landings in 1990 was mainly due to the reduction in spiny lobster and shrimp catches (including associate fauna), which will be examined later.

4.2 Important Features of Cuban Fisheries

The most noteworthy characteristics of Cuban fisheries include:

- The large number of species fished.
- The artisanal nature of most of the fishing gear and its great variety.
- The use of craft that rarely measure more than 20 metres in length, typical of short-distance local fisheries.

At least 150 species are currently fished and, with the exception of some (e.g., spiny lobster, shrimp, small tuna, oyster, crab, clam, sponge and turtle) which involve targeted fishing, the fishery is multi-specific.

These two connected features (many different species and the concurrent fishing of several species), which require the use of very different techniques, are the greatest impediments to resource evaluation and the exploitation of fishery resources in tropical and subtropical waters throughout the world.

Generally, high diversity goes hand in hand with low relative availability and few concentrations able to support a sustained fishing effort throughout the year. The cost and effort required to land one ton are generally high, making it not always economically viable.

The fishing gear currently used is artisanal and extremely varied, with the exception of shrimp nets. Ritzhaupt (1965) noted, and his observation is still valid, that the great variety in methods and fishing gear stems from the natural conditions to which Cuban fisheries has adapted.

4.3 The More Important Species and Groups

The relative importance of each of the species or species groups featured in the present statistical system is provided in Table 1 and Fig. 6.

The group with the highest economic value for the Cuban fishery sector is the crustaceans, which in addition to the Caribbean spiny lobster (Panulirus argus), the white shrimp (Penaeus schmitti) and the pink shrimp (P. notialis), also include the land crab (Cardisoma guanhumi), the stone crab (Mennipe mercenaria) and, since a few years, the swimcrab (Callinectes spp.).

In contrast to the crustaceans, where a few species have high economic importance, some 150 fish species are caught in Cuba, the main ones being (Baisre 1985a):

Table 1. Relative importance of various species for which the current statistical system records catch (1986-1990). (Source: MIF Statistics)

Species or group	% of EEZ total
Molluscs	6.1
mangrove cupped oyster (*Crassostrea rhizophorae*)	3.2
"goat foot" clam (*Arka zebra*)	2.5
queen conch (*Strombus gigas*)	0.3
Crustaceans	24.0
lobster (*Panulirus argus*)	15.4
shrimps (*Penaeus schmitti* and *P. notialis*)	5.3
stone crab (*Menippe mercenaria*)	0.1
land crab (*Cardisoma guanhumi*)	1.3
swim crab (*Callinectes sapidus*) mainly	1.7
Fish	11.7
Pelagics	
bonito and albacore (*Katsuwonus pelamis* and *Thunnus atlanticus*)	2.8
billfish and swordfish (Xiphidae and Istiophoridae)	0.4
sharks	3.5
Spanish, king and painted mackerel (*Scomberomorus* spp.)	0.8
carangids and jack mackerel (*Caranx* spp.)	0.4
sardines (*Harengula* spp.)	0.7
Atlantic herring thread (*Opisthonema oglinum*)	3.1
Demersals	26.7
mutton snapper (*Lutjanus analis*)	1.6
grey snapper (*Lutjanus griseus* and *L. cyanopterus*)	0.6
cane snapper (*Lutjanus synagris*)	2.6
yellowtail snapper (*Ocyurus chrysurus*)	1.2
Nassau grouper (*Epinephelus striatus*)	0.4
grunts (*Haemulon* spp.)	2.7
mojarra and patao (Gerridae)	1.8
mullet (Mugilidae)	0.7
porgies (*Calamus* spp.)	0.6
Other fish	14.5
Trash fish	30.2
Turtles	1.1

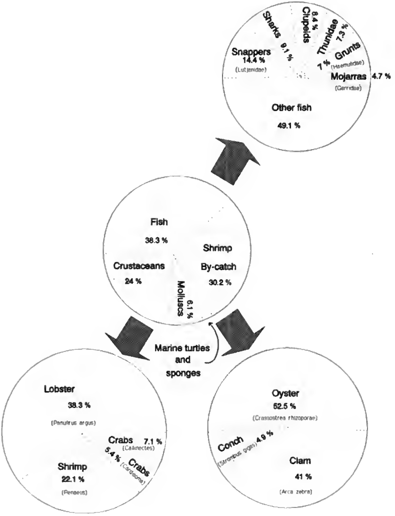

Fig. 6. EEZ catch composition in Cuba by percentage. Average figures for 1986-1990

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DEMERSALS	Estuarine	Mugilidae (mullet) Gerridae (patao and mujarra) Other species (seabass, croaker)
	Turtlegrass and reef areas	Lutjanidae (snapper and similar) Serranidae (grouper, wreckfish and related Pomadasydae (grunt) Other species
	Inshore	Clupeidae (pilchard and Atlantic thread herring) Engraulidae (anchovies are only a potential resource)
PELAGIC	Coastal intermediate waters	Carangidae (carangids and jack mackerel) Scomberomorus (King, Spanish and painted mackerel) Shelf shark (numerous species) Ocean shark (various species)
	Oceanic	Tuna (bonito and albacore) "Billfishes (billfish, marlin and swordfish)

The molluscs with the greatest commercial importance in Cuba are the mangrove cupped oyster (Crassostrea rhizophorae), the "turkey wing" clam (Arca zebra) and the queen conch (Strombus gigas).

Sea turtle species include the green turtle (Chelonia mydas), the loggerhead turtle (Caretta caretta) and the hawksbill turtle (Eretmochelys imbricata). There is also a specialized sponge sector based mainly on the capture of female sponges (Hippiospongia lachne and H. gossypina) and male sponges (Spongia spp.).

4.4 Lobster

Lobster is fished everywhere in Cuba though a larger proportion of landings are made on the south coast. There is territorial division with limited access to a specific number of vessels. There are also regulations on the number of gear, a closed season (90-120 days) during the spawning season, and a minimum legal size (6.6 cm cephalothorax length). A thorough description of fishing areas, catch statistics, gear and general biological data are provided in Cruz et al., (1987). Lobster fisheries were underexploited (Fig. 7) until 1955 with catches below 1000 T per year and the use of completely manual gear. The period of growth lasted until 1965 with catches amounting to some 9 000 T per year, a level that remained relatively constant between 1965 and 1977 (period of stabilization). There were sudden drops in 1960 and 1977 because of juvenile overfishing in previous years due to the indiscriminate capture of small specimens. The fisheries management period began in 1978 with the new fisheries regulations that established a longer closed season (from 45 to 90 days) and much stricter control of minimum legal size. The significant fall in catch in 1990 appears to be due to the sudden drop in three-year olds (see Puga et al., in

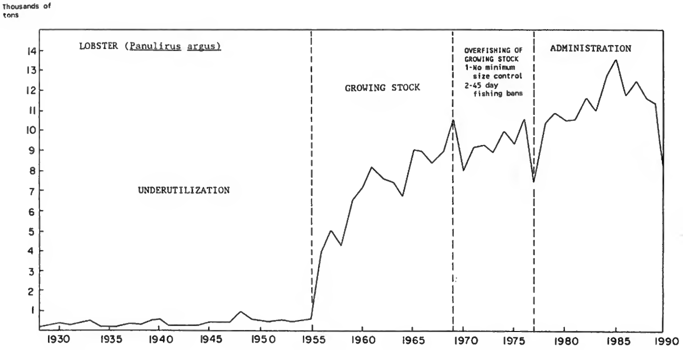

Fig. 7. Spiny lobster catch trends

press) probably because of the high juvenile mortality inflicted by hurricane "Gilbert" in nursery areas late in 1988.

4.5 Shrimp

As for lobster, there is territorial division and limited access to shrimp fisheries. Shrimp stocks are found in areas with heavy fluvial influence, mainly the Gulfs of Guacanayabo and Ana Maria and some bays and coves. Shrimp fisheries were below capacity until 1953, exclusively involving the white shrimp caught with cast nets.

The trawlnet was introduced in La Broa in 1953 and the pink shrimp also began to be taken. The trawl fisheries moved to Santa Cruz del Sur in 1954 because of overfishing, at the beginning of the period of expansion (Fig. 8). After 1959 the catch grew steadily with general trawlnet use, more fishing craft and various technological enhancements that increased catch capacity. Shrimp stocks were overfished from 1977 with activities far in excess of Total Allowable Catch (TAC).

The effort was sharply reduced in 1983 and other measures were taken to enable shrimp resources to recover and to initiate the management period (Baisre and Zamora, 1983).

Following a drastic reduction in effort, catches levelled off at around 4 500 t/year then fell abruptly in 1989, in spite of the fact that there had been no increase in fishing effort. This fall, resulting from extremely low recruitment, is attributed to a deterioration in juvenile nurseries caused by the following combination of factors: a) reduction in river outflow due to increased dam construction; b) prolonged drought between 1983 and 1988; c) the very hot winter of 1989 with few polar cold fronts.

Catches fell even lower in 1990 because of additional measures to control the fishing effort in the hope of offsetting the low recruitment levels.

4.6 Tuna

Small tuna such as bonito (Katsuwonus pelamis) and albacore (Thunnus atlanticus) are mainly fished in western oceanic waters along the whole north coast of Pinar del Rio as far as the Bay of Pigs in the south (Suárez Caabro and Duarte Bello, 1961), using rod, line and live bait. Tuna species also began to be fished in 1965 in the Old Bahama Channel northeast of Cuba (Carles, 1972).

Though this fishery was introduced in Cuba by Japanese residents in 1932 (Palomera, 1958), commercial fishing began only in 1941 (Rawlings, 1953). There has been practically no underexploitation of tuna stock (Fig. 9), with landings increasing steadily between 1949 and 1960, when total catch amounted to over 3 000 t. The lower figures of 1960 - 1964 were due to the limited market for canned products resulting from the US trade embargo. Catch levels have remained stable in recent years at around 2 000 t/year.

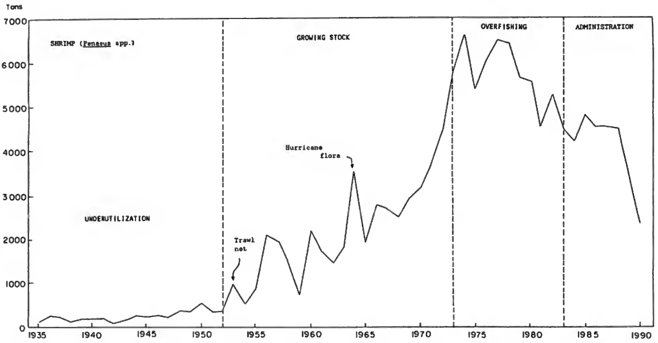

Fig. 8. Shrimp catch trends over time

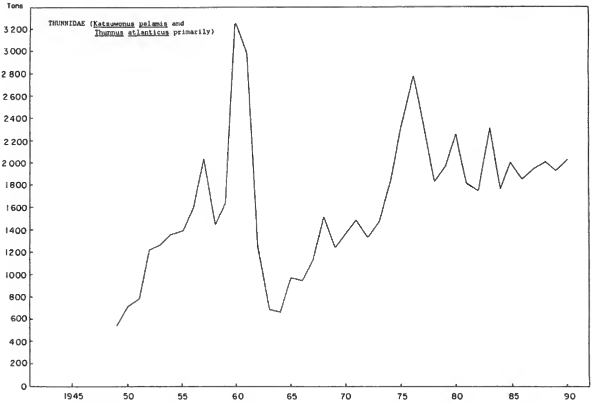

Fig. 9. Small tuna catch over time

4.7 Estuarine Fish

The two main groups of estuarine species are the mullet (Mugilidae) and the mojarra (Gerridae). They are commercially significant in the estuarine systems of the Gulfs of Ana Maria and Guacanayabo and in the northeastern bays and coves in the section between the bays of Nipe and Nuevitas.

Mullet is fished with gillnets and set nets (tranques) at the mouths of coastal lagoons, particularly during the spawning migrations (Alvarez-Lajonchere, 1978), when over 50% of the catch is made.

The mojarra (Gerridae) and mullet are the most important species in the coastal lagoon (Gonzalez Sanson, 1983) and estuarine areas. These fisheries are therefore limited to the southeastern shelf of Cuba and the northeastern bays and coves. While mullet catches have fallen considerably since 1984, mojarra landings have risen sharply since 1980, now amounting to over 1000 t/year (Fig. 10).

4.8 Reef Demersals

Demersals in the areas with hard beds, coarse sediment and coral reefs are the most important group of fish species in economic terms, not only for Cuba but for all the island countries in the region. Though collectively referred to as "reef fish", these species are not in fact genuine reef dwellers as they include species (Lutjanidae, Serranidae, Pomadasydae) which grow bigger and faster than authentic reef species (Scaridae, Acanthuridae, Balistidae, Holocentridae, etc.). These species are topographically associated with the reef and for the most part are trophically associated with turtlegrass (Thalassia).

Baisre (1985a) divides all the species into 3 different depth categories:

- Shallow water species: located mainly in the 1 to 15 m depth range and congregating near artifical reefs or other structures. The most representative species are the lane snapper (Lutjanus synagris), the grey snapper (L. griseus) and the grunts (Haemulon spp.), although there are also younger specimens of the mutton snapper (L. analis), the yellowtail snapper (Ocyurus chrysurus) and occasionally various serranods. They are usually caught from artificial reefs with shallow-water traps and seines. Some of the main species are caught during the spawning season with different types of set nets (tranques) and many have been intensively fished and even overfished.

- Shelf-edge species (set-nets): These are mainly found in the 15 to 50m depth range and include different kinds of serranids that are usually fished with mid-water traps or pots, though they also include adult mutton and yellowtail snappers that are fished with hook and line during the spawning season. Another important species is the Nassau grouper (Epinephelus striatus).

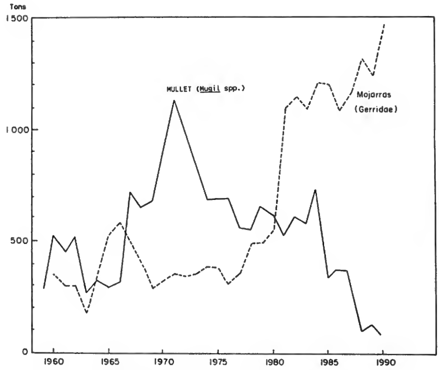

Fig. 10. Estuarine fish catches over time

- Deep-sea species: These are generally found below 50 m and include various snappers (Lutjanus vivanus, L. bucanella) and groupers (Epinephelus spp.) which are fished sporadically with deep-sea fish traps and bottom longlines. They also exhibit notable depth-determined distribution.

Figures 11 to 15 illustrate the historical development of catches of the main demersal reef fish.

4.9 Coastal Pelagics

The most important coastal pelagics for Cuban fisheries are the pilchard and Atlantic thread herring (Clupeidae), the jack mackerel and related species, (Carangidae) and the Spanish mackerel and related species (Scomberomorus spp.), which occur in a gradient from the coast to the shelf-edge (Baisre, 1991).

Among the clupeoids, the clear geographical segregation of the Atlantic thread herrings (Opisthonema oglinum) and pilchards (Harengula spp.) produce two clearly distinguishable fisheries. The Atlantic thread herring is more abundant off the continent than in the Caribbean islands (Reintjes, 1979) and is found in Cuba in relatively large concentrations in estuarine areas in the north and south (Baisre, 1991). Valdés and Sotolongo (1983) provide a detailed description of Cuban Atlantic thread herring fisheries, while Sotolongo and Valdés (1991) describe the age and growth parameters. According to Reintjes (1979) the Carangidae species of interest to fisheries form two clearly defined groups. The Cuban species fall within the group of non schooling of demersal large fish and are generally caught with hand-lines and nets. In Cuba the Caranx species are a by-catch, depending on whether the fisheries involve seines for reef demersals or gillnets for mackerel. The fishing of the various Scomberomorus is virtually limited to the southeast shelf of Cuba using gillnets, as described in detail by León and Guardiola (1984).

Figure 16 outlines the catch trends for Atlantic thread herring and Scomberomorus which are the most economically significant coastal pelagics now that the catch of jack mackerel and related species (Caranx) has levelled off at 500 T per year.

4.10 Oceanic Pelagics and Shark

Oceanic pelagic fisheries are of little economic importance in Cuba except for coastal and oceanic shark fishing.

Billfish, marlin and swordfish are caught with drift longlines using some 100-250 hooks, a method introduced in the early 1950s (Guitart, 1964). There have been a number of modifications and there are now a number of variations in this method (Moreno and Rodríguez, 1984).

Shark fishing is one of the most extensive Cuban fisheries. Though mainly involving the use of bottom and drift longlines, shark are also caught as a gillnet by-catch. Shark landings totalled over 2 000 T per year since 1968 (Fig. 17). The slow rate of growth of most of these species together with the fact that they are at one extreme of the marine food chain makes them very vulnerable to fishing and can make stock assessment very

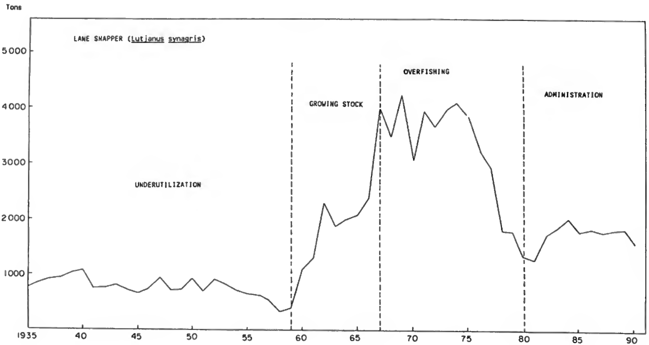

Fig. 11. Lane snapper catches over time

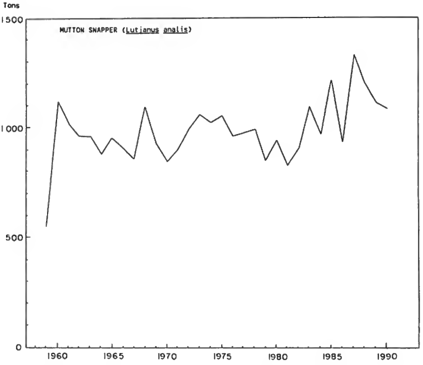

Fig. 12. Mutton snapper catch trends over time

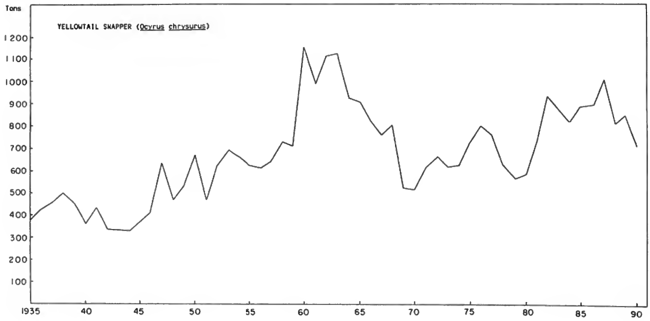

Fig. 13. Yellowtail snapper catch trends over time

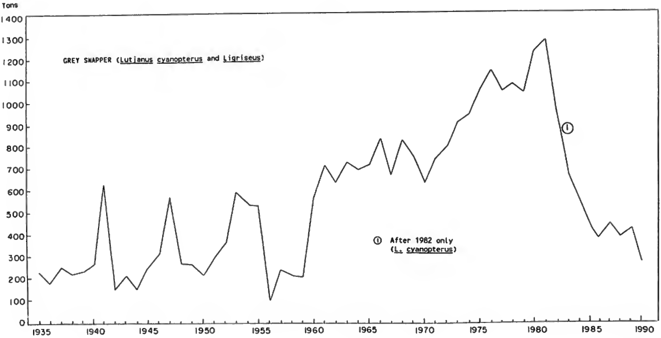

Fig. 14. Grey snapper catch trends over time

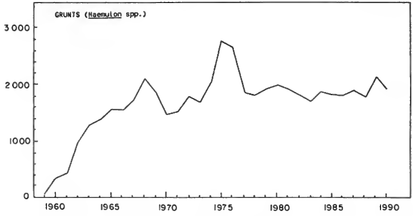

Fig. 15. Grunt catch trends over time

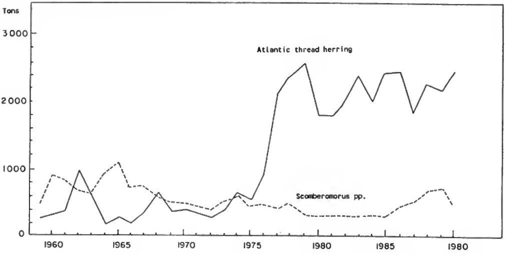

Fig. 16. Catch trends for Atlantic thread herring and Spanish mackerel (Scomberemorus spp.) over time

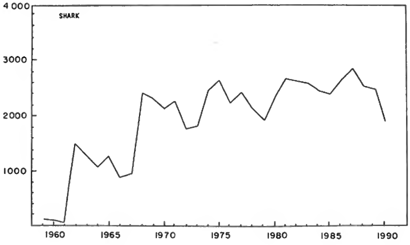

Fig. 17. Shark catch trends over time

difficult, as short-term stock assessments may not accurately reflect shark potential (Springer, 1979).

4.11 Small-scale Specialized Fisheries

Despite their limited economic importance for domestic fisheries, there are specialized fisheries for a group of species, some going back a considerable number of years (oyster, clam, conch, stone crab, land crab, swimcrab, sponge and sea turtle). Although these fisheries are not divided territorially, the nature and limited distribution of the species calls for specialized fisheries by specific enterprises.

Oysters: Oysters are gathered in the mangrove areas near river mouths and inside the bays, coves and muddy coastal sections (Pérez-Farfante, 1954), particularly the numerous bays between Nuevitas and Nipe on the north coast and along the south coast (Baisre, 1985a). The period of underexploitation lasted up to 1959 when oyster gathering was controlled by a minimum size of 50 mm.

The elimination of size limits in 1960 produced a growth period in the fishery that lasted until 1970. The catch fell between 1970 and 1974 because of indiscriminate oyster fishing and pollution in certain coastal zones. Landings increased in 1975 with the addition of "oyster farm" production. Landings from natural catch and oyster farms have now levelled off at some 2 300 t/year (Fig. 18).

Clams: The clam species known as "turkey wing" has a very limited distribution in Cuba, is only fished on the southeast shelf of the area between the ports of Guayabal and Santa Cruz del Sur in separate natural shoals. Clam fisheries increased considerably from 1980 with catches stabilizing from 1985 at around 1 800 T per year (Fig. 18).

Land crab: The land crab lives in tunnels and holes burrowed in marshy areas near the coast, but because of its marine ancestry the egg-bearing females migrate to sea in large numbers to spawn (Bright, 1977). These crabs are fished in Cuba almost exclusively during the spawning season, with wide ditches being installed before the first spring rains which seem to trigger the migration. The fishing of this species is relatively recent (1968) with catch levels exceeding 1 000 t in 1975. The ban on the capture of "berried" females and the setting of a minimum legal size of 12 cm (breadth of cephalothorax), introduced because of signs of overfishing, have led to a reduction in catch in recent years (Fig. 19).

The stone crab: This species is not very numerous in Cuba and is limited to the northern coastal area of Villa Clara and Ciego de Avila and the La Broa cove. Its great vulnerability, limited population and the lack of fishery regulations have resulted in overfishing as evidenced by the catch data (Fig. 20).

Sea turtle: Sea turtles are mainly fished in the cays surrounding the Cuban archipelago, an particularly the open sea side, with gillnets set on the surface or at mid-depth. Catches

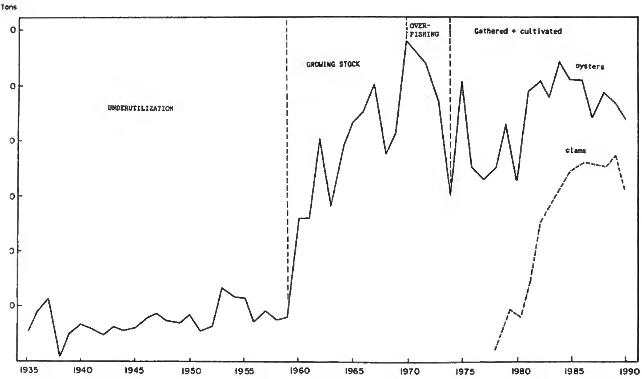

Fig. 18. Oyster and clam catch trends over time. Fishery phases refer exclusively to the oyster fishery

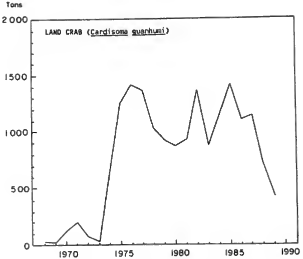

Fig. 19. Land crab catch trends over time

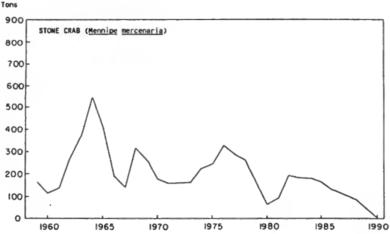

Fig. 20. Stone crab catch trends over time

rose rapidly after 1966 reaching more than 1 000 t/year. Fishery regulations were introduced in 1976 to protect this species during the spawning season (Fig. 21).

Sponges: Sponges are fished exclusively in the Gulf of Batabanó and on the northeastern shelf. The fishing gear has remained much the same as in the last century with the use of the glass viewer and hook ("vidrio", "mirafondo" and "gancho". Though catch levels have fluctuated considerably because of changes in demand, landings have increased since 1975, reaching an annual total of more than 50 t (Fig. 22).

5. POPULATION ASSESSMENT

5.1 Lobster

The most recent estimate of the potential lobster catch was made by Puga et al. (in press), using a production model based on the PRODFIT programme (Fox, 1975). The population profile was also studied by these authors using industry data processed into size frequencies (Sotomayor and Cruz, in press) through cohort analysis following the methodology of Mesnil (1980). Their conclusions are that the potential catch amounts to some 12000 t/year, that the lobster stock is being fully exploited and that recruitment is falling. Table 2 provides data on potential catch and optimum effort for each of the fishing zones, and on the population assessment parameters (Fig. 23).

At the same time, Cruz et al. (in press) calculated the optimum size at first capture using the Beverton and Holt (1957) yield-per-recruit production model. They also simulated various effort regulatory options based on different closed seasons. They calculated that an increase in size at first capture from 67 mm (length of cephalothorax) to 77 mm with a closed period of 90 days would increase the catch by 890 to 1 200 t/year, earning an extra 2.4 to 4.4 million dollars (Fig. 24).

5.2 Shrimp

The overfishing which seriously affected shrimp fisheries in the early 1980s encouraged new stock assessments. Studies undertaken have covered the main criteria needed for an accurate evaluation of the fishery situation: population identification (Villaescusa et al., 1985), migratory patterns (Rodríguez and Pérez, 1982), reproduction potential (Guitart et al., 1985a), the identification of spawning areas and seasons (Guitart et al., 1985b), feeding (Anderes, 1982), juvenile distribution and abundance patterns (González et al., 1984), and tagging and recapture experiments (Pérez, et al., 1988). On the strictly fishery level, there is enhanced understanding of the technological and historical development of shrimp fisheries (Baisre and Zamora, 1983) and a comprehensive shrimp-fishery management system has been implemented (Baisre, 1983; Rodríguez, 1988) enabling the fishing fleet to be positioned according to a "profit" index (Pérez, 1982). Studies have also been conducted to standardize the fishing effort (Rodríguez and Morenza, 1984) and simulations have been made of the impact of different

Table 2. Potential catch (C) and optimum effort (opt. E) for the lobster fishery in each major fishing area. (From Puga et al., in press)

Fishing Zone	C (t)	Opt.E No. of gear x 10^3)
Gulf of Batabanó	7 087	131.7
Southeastern Region	2 810	45.7
Northeastern Region	2 06	1 034.7*
Northwestern Region	362	16.4
Total for Cuba	12 318	

Parameters used:

1. Length/weight ratio: $W = 0.076\ L^{2.7242}$
2. Growth parameters: $L = 46$ cm (total length)
$K = 0.22$
$t = 0.38$
3. Natural mortality: $M = 0.3$

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* The effort in this area is expressed as the number of times each gear was worked

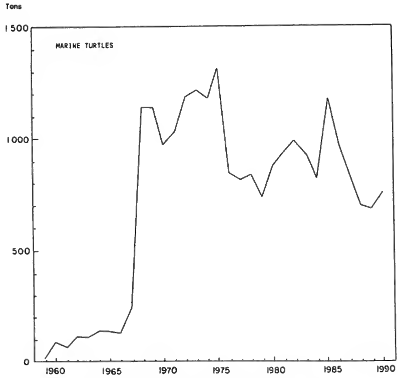

Fig. 21. Marine turtle catch trends over time

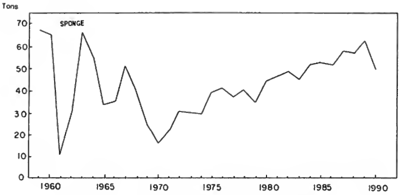

Fig. 22. Sponge harvest trends over time

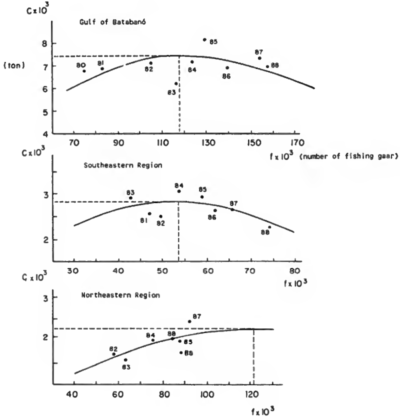

Fig. 23. Application of the production model (PRODFIT) to lobster fisheries in Cuba's main fishing areas. (From Puga _et al._, in press)

management policies based on bio-economic parameters (Pérez and Rodríguez, 1985).

Evaluations of the potential shrimp catch in the regions of the Gulf of Ana María (Pérez et al., 1984), Santa Cruz del Sur (Pérez and Puga, 1982) (Fig. 25) and Manzanillo (Pérez and Puga op. cit.,) produce the respective values of 3 340 t, 1 150 y and some 1 500 t/year, with a maximum effort of 8 340, 6 540 and 8 430 vessel/fishing/days respectively (Table 3). These data indicate a MSY for the whole of Cuba of some 6 000 t/year with maximum effort values of some 23 000 vessel/fishing/days. Both the MSY and the maximum effort refer to fisheries under conditions of equilibrium which is far from being the case in shrimp fisheries and particularly Cuban shrimp fisheries, which is also affected by recruitment deficiencies from adverse environmental conditions in the nursery areas.

5.3 Reef Demersals

As mentioned in the introduction, the central problem in evaluating reef demersal populations is the lack of information on fishing effort due to the multiplicity of fishing methods and the concurrent fishing of several species. Nevertheless, some of the more important species have been assessed individually in particular areas. The most striking findings to emerge from the review of Cuban fishery resources by Baisre and Páez (1981) are listed below. To enhance infórmation on demersal fish stocks, Table 4 compiles the most recent data on the growth of various important species.

Obregón et al. (1990) have recently used the production models of Fox (1975) Csirke and Caddy (1983) to calculate the maximum sustainable yield for lane snappers in the northeastern part of the country, producing annual figures of 220 and 251 t respectively. The yield-per-recruit model of Beverton and Holt was also applied, leading to maximum yield-per-recruit (39 g) for an age at first capture of 1.84 years (16.4 cm).

Using size samples and the probability method (Cassie, 1950), Ramos and Pozo (1984) determined a growth equation for the white grunt (Haemulon plumieri) and, applying the Beverton and Holt yield recruit model, identified a potential catch of 500 t/year. In both cases these evaluations should be considered as provisional as they are based on very short time series.

6. OUTLOOK

6.1 Fishing Effort

Cuban fisheries combine features of industrial and artisanal fisheries and have a level of development that is very difficult to compare with that of other countries in the area. Among the most notable characteristics of the current Cuban fishery situation are (Baisre, 1985a):

- A relatively comprehensive organization of the whole production system, which includes a vast network of storage centres and facilities for the delivery, processing,

Table 3. Summary of Potential Catch (SPC) and maximum effort (max. E) for Cuban shrimp fisheries

REGION: GULF OF ANA MARIA Model: Pella and Tolison (1969) From: Perez and Puga (1982)					
Parameters	M	MSY (t)	Max.E (fish.days)	cpue_{MSY} (kg/vessel/fish.day)	r^2
	2.0	3 553	12 561	283	0.950
	0.99	3 345	10 855	308	0.980
	0.54	3 340	8 340	397	0.983
	0.3	3 622	4 351	833	0.982
REGION: SANTA CRUZ DEL SUR From: Pérez and Puga (1982)					
Schaefer model		1 517	6 540	232	
Fox Model		1 409	7 625	185	
REGION: MANZANILLO From: Pérez and Puga (1982)					
14 years					
Schaefer model		1 568	8 430	198	0.62
Fox model		1 547	9 618	171	0.64
8 years					
Schaefer model		1 637	6 972	250	0.686
Fox model		1 584	6 779	286	0.672

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Table 4. Age and growth data for different fish species

Common name	Scientific name	L	K	Method	Observations	Author(s)
"CC" Snapper	*Lutjanus bucanella*	60.08	0.12	tails	S.E. Region	Espinoza and Pozo, 1982
		66.68	0.08	otoliths	S.E. Region	Espinoza and Pozo, 1982
		60.21	1.05	tailbones	N.E. Region	Espinoza *et al.*, 1984
High seas snapper	*L. vivanus*	72.98	0.096	tails	N.E. Region	Pozo *et al.*, 1983
		75.67	0.10	tails	S.E. Region	Pozo and Espinoza, 1982
		79.55	0.07	otoliths	S.E. Region	Pozo and Espinoza, 1982
Mutton snapper	*L. analis*	80.75	0.116	tails	N.E. Region	Pozo, 1979
		88.0	0.1522	otoliths	Gulf of Batabanó	Claro, 1981b
		117.8	0.1000	otoliths	N.W. Region	Claro, 1981b
Lane snapper	*L. synagris*	38.3	0.190	otoliths	Gulf of Batabanó	Rodriguez, 1988
		50.2	0.1458	otoliths	Gulf of Batabanó	Claro, 1981a
		39.7	0.19	otoliths	Gulf of Batabanó 1981	Rubio *et al.*, 1985
		40.1	0.16	otoliths	Gulf of Batabanó 1982	Rubio *et al.*, 1985
		2.03	0.204	otoliths	Gulf of Ana Maria	Pozo *et al.*, 1991
		42.24	0.17	otoliths	Gulf of Guacanayabo	Pedroso and Pozo, 1991
Grey snapper	*L. griseus*	51.07	0.1950	otoliths	Gulf of Batabanó	Claro & Bustamante, 1977
		1.3	0.24	otoliths	Tunas de Zaza	Báez *et al.*, 1980
"Arará" grunt	*Haemulon plumieri*	25.57	0.433	length/	N.E. Region	Ramos and Pozo, 1984
Atlantic thread	*Opisthonema oglium*	19.47	0.59	otoliths	S.E. Region	Sotolongo & Valdés, 1991
Ladyfish	*Elops saurus*	42.6	0.278	scales	S.E. Region (1964)	Carles, 1967
		49.76	0.212	scales	S.E. Region (1965)	Carles, 1967
Mullets	*Mugil hospes*	30.27	0.283	bones	T. de Zaza (males)	Alvarez-Lajonchere, 1980
		51.78	0.15	bones	T. de Zaza (females)	Alvarez-Lajonchere, 1980
	Mugil trichodon	28.64	0.139	bones	T. de Zaza (both sexes)	Alvarez-Lajonchere, 1981
	M. curema	43.2	0.100	bones	T. de Zaza (males)	Alvarez-Lajonchere, 1981
		88.8	0.110	bones	T. de Zaza (females)	Alvarez-Lajonchere, 1981

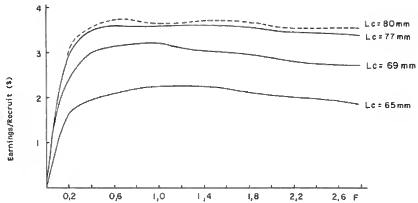

Fig. 24. Economic effects (earning-per-recruit) from changing fishing mortality (F) and changing size-at-first-capture (expressed as cephalothorax length). (From Cruz *et al.*, in press)

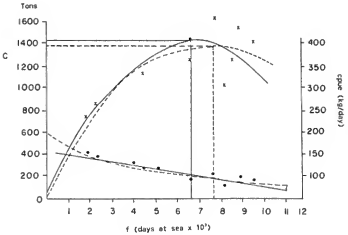

Fig. 25. Schaefer models (unbroken line) and Fox (dotted line) applied to the shrimp fishery in the Santa Cruz del Sur region. (From Pérez and Puga, 1982)

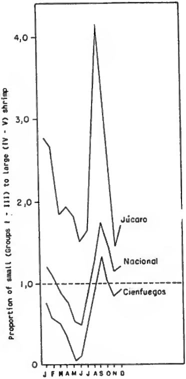

Fig. 26. Local and seasonal differences in size composition for the shrimp fishery. Note peak recruitment in September and the characteristic very small sizes of the Júcaro area and characteristic larger sizes of Cienfuegos (Industry data)

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transportation and distribution of fish products and for the maintenance, repair and construction of fishing vessels.

- A near full exploitation of stock in nersitic waters with the minor exception of a few species in deeper waters near the shelf edge, at a depth of below 100 m, and of oceanic pelagics.

- Very varied fishery technology determined by the diversity of the shelf topography and of the species fished: maximum efficiency within the limits imposed by the lack of mechanization, by traditional fishing skills and by the way production is organized.

Cuban fisheries are now mostly fully developed. As indicated by Caddy (1984), in this phase enhanced know-how plays a very important role in maintaining catch levels, as the fishermen are better able to identify "pockets" of abundance, and better able to exploit seasonal fluctuations (runs, homing) and to increase fishing trip performance.

Clearly when fisheries are fully developed, the risks of overfishing may be particularly great for highly available (vulnerable and accessible) species, and/or when non-selective gear is used. Table 5 shows that most of the species and assemblages fished in Cuba have a high risk of being overfished, because they are found in very limited and accessible areas, because they form spawning clusters that facilitate capture, because they are caught with non-selective gear, or because of a combination of these factors in addition to their individual market value.

6.2 Fisheries Management

Lobster: There is a long tradition of lobster fishery management going back more than 50 years. According to Baisre et al. (1985) a longer closed season (from 45 to 90 days) and stricter control of minimum size at capture led to significant catch increases from 1978. The extensive use of floats or "casitas" may have limited predation (reducing natural mortality) but this hypothesis needs to be supported by field data (Caddy, 1990). The dramatic fall in lobster catches in 1990, attributed to high juvenile mortality caused by hurricane "Gilbert" in 1988, indicates that additional measures are needed to control the fishing effort. An increase in minimum size at capture (Coyula, 1983; Cruz et al., in press) is an option worthy of consideration.

Shrimp: The strategic objective of the Cuban Fishery Administration is to maximize foreign currency earnings by taking large-size specimens.

Though this objective is facilitated by the fact that there is no competition in Cuba between the small-scale fishing of estuary juveniles and the industrial fishing of adult shrimps in deeper waters, some areas contain a large proportion of juveniles that may face high mortality unless appropriate measures are taken.

Table 5. Risk of overfishing for the main species of commercial interest in Cuba (from Baisre, 1985a)

Species or group	Vulnerability	Accessibility	Gear selectivity	Economic value	Other	Risk
Oysters	high (sessile)	high (shore)	Hand gathered	high	Susceptible to pollution	high
Conch	high (highly sedentary)	high (shallow)	Hand gathered	high	-	high
Clams	high (sessile)	high (shallow)	none (set nets)	medium	very small area	high
Land crab	high (spawning migrations)	high (land based)	none (ditches)	low	deep ditches	high
Stone crab	medium	high (shallow)	low (traps)	high	very small area	high
Sponges	high (sessile)	high (shallow)	Hand gathered	sometimes	very small area	high
Turtles	high (as hatchling turtles attempt to return to sea)		medium (low gillnets)	high	low reproductive rate	high
Shrimp	high (assemblages)	high (shallow)	low (drawnets)	very high	-	high
Lobster	high (migrations)	medium	low (dragnets,	very high	-	high
Lane snapper	high (spawning)	high (shallow)	none	high	-	high
Mutton snapper and grey snapper	high (spawning assemblages	low (shallow waters)	high (hook and line)	high	-	high
Nasau grouper	high (assemblages)	low (deep waters)	medium (traps)	high	-	high
Yellow tail snapper	high (spawning assemblages)	low (semi-pelagic)	high (hook and line)	high	-	high
High seas	low	low (+ 100 m)	high (longline)	high	-	high
Shark	high (very depredatory)	medium	high	high	low reproductive rate	high
Sardine and thread herring	high (schools)	high (coastal)	none (beach seines)	low	-	high
Scombers	medium	medium	high (trawling)	high	-	med.
Bonito and albacore	high (schools)	medium (migratory)	high (hook and	high	-	low
Billfish	medium	medium (migratory)	high (longlines)	high		low

The regulation of mesh size has sometimes been considered relatively ineffective given its poor selectivity, but the measure does have the following practical advantages: greater average weight and price per kilogram; reduced fishing mortality among juvenile stock; potential and measurable gains within one year given the shrimp's short life-cycle and rapid growth (García and Le Reste, 1981).

Closed seasons during the recruitment months or permanent or temporary closures in coastal strips accessible to the trawl fleet and with high proportions of juveniles are also effective fishery mmanagement tools that have been used in Cuba to complement the spatial and seasonal regulation of the fishing effort (Baisre and Zamora, 1983).

However, none of the above measures can alone avert overfishing as their implementation and consequent benefit encourages an even greater fishing effort which can quickly offset the immediate economic gains (Pearse, 1980).

The regulation of fishing effort through administrative restrictions on the number of vessels or nets overcomes the above difficulties by preventing overfishing, and also minimizes costs (García and Le Reste, op. cit.). To be completely effective this method of control needs to take into account seasonal stock variations.

In the case of Cuba, where the shrimp has both a marked seasonal and geographic size profile (Fig. 26), a sufficiently flexible and dynamic system is needed to control the effort in terms of area and season, as this may have repercussions on profit and is presently the only really effective means of protecting recruitment. A larger mesh size will allow small shrimp to escape and survive, but this alone may not be sufficient (Pérez, et al., 1984).

The territorial organization of shrimp fisheries and the statistical and technical/operational supervision and management systems for the shrimp fleet have already been described in detail and do not need to be repeated here (Baisre, 1983; Baisre and Zamora, 1983 and Baisre et al., 1985). Nor do the findings on the management of specific fisheries such as that of La Broa inlet (Puga, et al., 1980) or Manzanillo (Rodríguez, 1983).

For shrimp management, it is particularly important to understand that recruitment can vary considerably from one year to another with no manifest change in adult population. The size of the adult population is therefore largely determined by the success of the previous spawning season, modified by fishing intensity between recruitment and spawning season (FAO, 1983). This explains why there are unexpected changes in catch levels from one year to the next which do not appear to be related to changes in fishing effort. They also indicate the need to take these variations into account when planning production. With these systems, an apparently low quota based on average conditions may, in adverse environmental circumstances, be too high for the production capacity of the system. In such cases the resultant effort could be too great and detrimental even without exceeding the quota (Caddy, 1983).

"Reef" demersals

"Reef" species are those dwelling in reef areas with low food availability and high inter-species competition. These species generally have a long life cycle, low reproductive rates and limited movement (Stevenson, 1978). For this reason they have developed strategies to maximize exploitation of available food resources and shelter, and ensure a high survival rate. According to Baisre (1985a) the main strategies, all of which are important for fisheries, are:

- Organization of spawning (and possibly recruitment) periods;
- Depth distribution not only by species but also by size; (the larger species and specimens are found at greater depths);
- Trophic organization both of individual species and size categories (the larger species and specimens tend to be more piscivorous).

The exploitation of small size specimens is therefore the result of an explicit tendency of fishermen to fish in shallower waters which not only produce greater yields but can be fished more easily, and an implicit tendency of most of the species to group according to size and therefore depth. In general terms, therefore, the younger individuals are overfished whilst the older population is underfished. Under these conditions the overfishing of growing stock is more likely than the overfishing of recruitment stock except for species caught during the spawning season. As many of the specimens caught in the shallower areas have not yet reached sexual maturity nor full growth, this form of fishing is a kind of "Lilliput strategy" (Pauly, 1979) that may be relatively unproductive and eventually cause the fishery to collapse. On the other hand, as the total transfer of fisheries to deeper areas would incur greater costs, with the reduced use of the more productive fishing gear, the most appropriate strategy appears to be to change size at first capture through the use of different selective gear. These measures would help to reduce fishing mortality and increase size at first capture to achieve maximum output.

Though an increase in size at first capture has often been advocated, there are in practice few scientific data to evaluate fully the impact of such measures. Nevertheless, reducing the overfishing of growing stock in intensively fished populations appears to be the best option (Huntsman, 1980; Stevenson and Stuart Sharkey, 1980) to manage multi-species fisheries given that other fishing effort regulations are not particularly viable, impractical to implement (e.g., minimum size, quotas) or may be inappropriate from the economic point of view, (e.g., total bans during the spawning season or the prohibited use of certain kinds of gear). According to Ramos and Obregón (1983), the use of selective gear such as "viveros" or selector rings in nets, would lead to long term benefits for seine fisheries on the northeastern shelf.

Oceanic pelagics

When determining a strategy for the fishing and management of oceanic pelagics, it is necessary to consider the differences between more or less stationary species and typical migratory or even trans-ocean species.

In Cuba, ocean pelagics are fished from small craft very close inshore, the fishermen tending to remain in known traditional areas. The fishing season is very short and is heavily dependent on the availability of bait (Baisre, 1985a).

Though it has been suggested that the operational radius be extended and fishing technologies improved, the low availability of these species in Cuban waters appears to be a disincentive to the necessary investment.

Specialized fisheries

Most of the small-scale specialized fishery species share certain characteristics. Except for the oyster, conch and turtle, they are found in very specific areas. The fact that some are sessile (oyster, clam, sponge), are unable to cover large distances (conch, crab) or have very specific spawning behaviours (turtle, land crab), makes them easier to catch and increases their exposure to overfishing and land-based contamination.

The fishing of each of these species requires considerable care and the most appropriate management measures appear to be catch quotas or specimen size limitations.

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ISBN 92-5-103183-5 ISSN 0429-9345
9 789251 031834
M-43 T0602E/1/7.93/2300